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THE UNITED STATES COAST SURVEY.

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THE frequenter of any of our larger libraries may have seen upon the lowest shelf of some out-of-the-way alcove a group of substantial quartos clothed in solemn black and wedged tightly in by other heavy volumes, all of them bearing the most unmistakable evidence of enjoying a dignified repose and of being very seldom called for. If the visitor should draw out one of these huge quartos, blow the dust from the upper edges of the leaves and lay the volume open, he would find, perhaps, half its thickness taken up by various maps, any one of which, should he be rash enough to unfold it, will be a good exercise of his skill and patience to fold up again. If he turns to the text he will find himself involved in a mass of complex formula and elaborate discussions of various highly scientific subjects, the very language of which, for the most part, he will fail to comprehend. By this time he will be very apt to have seen enough, and will gladly return the volume to its resting-place, where it will continue its long slumber and accumulate a new coating of dust.

This group of neglected volumes cannot be purchased for any money. Probably no man except the proof reader has ever read one of them through, and yet they are a mine of wealth to the student of science, a noble monument of consummate skill and of patient industry, of long-continued toil and untiring devotion to duty. Learned men the world over have been glad to do honor to the authors. The results recorded are of immense importance alike to the farmer, the merchant, and the manufacturer. We have moreover in these volumes a remarkable example of the practical importance of the most abstract scientific research; an illustration of the general law that the conscientious investigation of truth for its own sake shall be rewarded by some unforeseen practical benefit. The works to which we refer are the "Reports of the United States Coast Survey," and from these documents and other scientific publications we propose to extract such facts as will show to the reader something of the objects, the methods and the results of the organization which has employed the best scientific talent of America for upwards of twenty years, and has produced results which are no less remarkable for their high scientific character than valuable to the industry of the country.

That commerce is of vast importance to any nation, and especially so to an isolated country like America, the reader does not need to be told, nor will he fail to see that the more the risks attending navigation are reduced, the better, not only for those directly engaged in

commerce, but also for *producers* in every part of the land. Indeed, so closely interwoven are the different branches of human industry that what affects commerce affects all. The results of the Coast Survey are thus not less important to the interior than to the seaboard states.

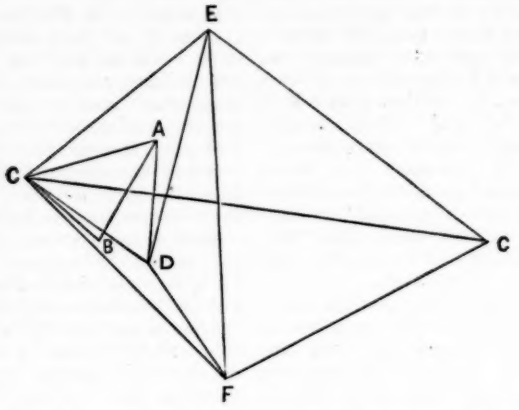
Prominent, if not chief, among the dangers of the deep are the reefs and shoals, the tides and currents that fringe the borders of the land. With a plenty of room and deep water the sailor has comparatively little to fear. It is, therefore, of special importance that the outline of the coast should be mapped with the utmost exactness, and more than this, that the knowledge of the nature and shape of the bottom from the shore out to the deep sea should be very complete, the more so as all beneath the water is hidden from sight and can only be shown to the navigator by correctly prepared charts. In clear weather, even though it be night, we may find no difficulty in working into a harbor provided with suitable beacons and lights; but in stormy weather, and worse yet, when all signals are swallowed up by impenetrable mists, the case is very different, and just here is where the admirable charts of the Coast Survey come in to take the tired mariner by the hand and lead him amongst rocks and shoals and shifting currents to an anchorage where he may lay firm hold of the land, safe from the dangers of the deep.

The two principal objects of the Coast Survey are thus plainly seen, viz.—first, to make an absolutely exact map of the outline of the coast, and, second, to prepare charts, which extending from the coast line out to deep water shall give the sailor as clear a knowledge of the nature and shape of the bottom as if the sea was drawn off and its bed laid bare.

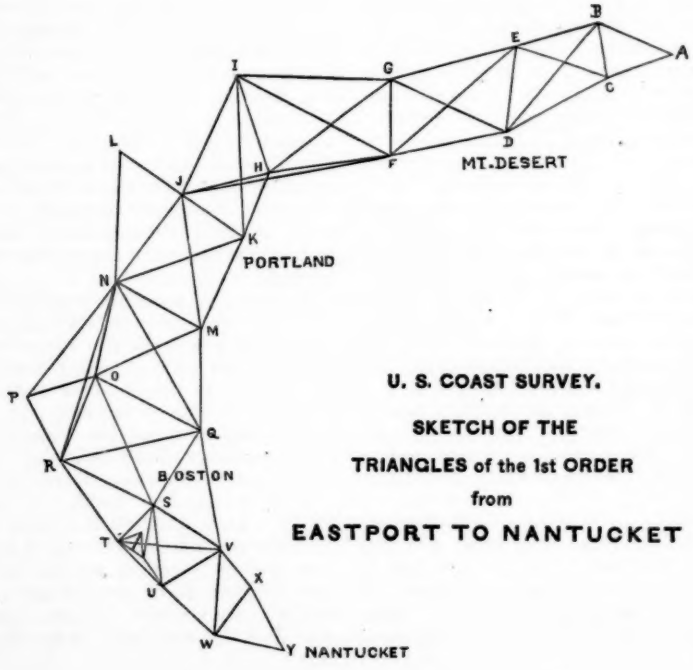
For the determination of points upon a coast reaching over many degrees of latitude the ordinary methods of surveying are not at all applicable. Surveys made upon the assumption that the surface of the earth is a plane would be so incorrect as to be worse than useless; and not only is it necessary to take into account the spherical form of the globe, but still farther the flattening of the sphere at the poles must be regarded or we do not obtain a sufficiently exact result. All of this precision in the requirement demand a corresponding amount of scientific knowledge and practical skill in the execution of the work. In fact, the making of the outline map of the coast has drawn upon all departments of Astronomy and Physics, and not only has the Coast Survey availed itself of all that was known, but it has invented new instruments and new methods of observation and of computation which have been adopted by astronomers both in this country and in Europe.

It will be evident at the outset that it would be impracticable, if not impossible, to determine the distance from point to point along the coast by direct measurement with a chain or other apparatus; for not only would such a line pass through swamps and woods and even into the water, but following the general trend of the coast it would be very crooked, and unless each change of direction was exactly determined we should not only make errors in the position of our line, but such errors would be carried along, and accumulating, would so distort the survey that when we undertook to lay our work upon the plans we should find a wide difference between the position of the various points as given by our measurements, and the position of the same points as determined by fixing their latitude and longitude by astronomical observation. The methods employed for locating the principal points along the coast avoids all such errors, and also saves much time and expense. The principle involved is the most elementary one in Trigonometry, viz.—that when we know one side of a triangle and two angles we can compute the remaining side. An extension of this simple principle, carried out, of course, with all the refinements of modern science, gives what is termed the Primary Triangulation, the extent and nature of which will be understood from the following sketches, in which Fig. 1 shows the commencement of the work resting on the Massachusetts Base, and Fig. 2 the whole system from Eastport to Nantucket. In Fig. 1 AB is a line on the Boston and Providence Railroad about ten miles long, measured with the utmost accuracy as hereafter described. From C, A, and B the several angles of the triangle ABC are measured, and thus the remaining sides AC and

BC become known. Next, from the stations D, A, and C the angles of the triangle ACD are measured, and also two angles of the triangle CDE, E being a station on one of the Blue Hills in Milton. From this point, as well as



from C, angles are measured to F and G, and by computation the lengths of all the lines represented in the sketch become as accurately known as if they had been measured directly. In the same way the triangulation is continued as in Fig. 2, which shows the triangles of the first order from Passamaquoddy



Bay to Nantucket, A being the Grand Menan, D Mount Desert, F Ragged Mountain, at Camden, I Mount Blue, at Farmington, J Pleasant Mountain, in Denmark, K Mount Independence, near Portland, L Mount Washington, M Agamenticus, near Portsmouth, N Gunstock, at Lake Winnepesaukee, O Unkonoonuc, near Manchester, P Monadnoc, in Cheshire County, N. H., Q Thompson's Hill, Gloucester, R Wachusett, in Princeton, S Blue Hill, in Milton, T Beaconpole, U Copecut Hill, V Manomet, W Indian Hill, on Martha's Vineyard, X a station on Cape Cod, and Y a point on Nantucket. The Massachusetts Base with its triangles is shown at T, but on a very small scale.

By this method of proceeding we fix the position of the several points with great exactness, regarding both the globular form of the earth and also the flattening of the globe at the poles; and when we say with great exactness we mean within a few inches. It may be asked how we know that our points are within so short a distance of being absolutely correct. We know it by selecting a suitable place on the ground near the end of our series of triangles and measuring a line five or six miles long with the utmost care. This line is then connected with our primary triangulation so that we can also obtain its length, independently of actual measurement, by computation. The calculated and measured lengths should, of course, be alike. Such a line is called a Base of Verification, and when it is remembered that a single false step in the whole immense chain of triangles would prevent this final agreement, we can appreciate the splendid practical science of the officers of our Coast Survey, which starting from its primary base and working through a chain of triangles over three hundred miles long, should vary no more than three or four inches in a base of verification five and one-half miles in length. Such results as this are, of course, only obtained by long-continued observations, with the most refined instruments, in the hands of the most skillful observers. The base of verification for the New England chain of triangles is a line about five and one-half miles long on Epping Plains, in Maine, and is shown in Fig. 2 by the short heavy line in the triangle C D E. The triangles connecting this line with the points C, D, and E are not shown on account of the small scale to which our figure is drawn.

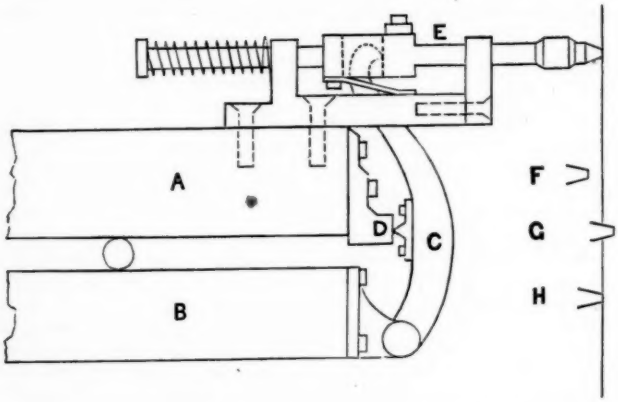
It will be observed that the triangles in Fig. 2 are very large, the sides of some of them being as long as seventy miles. This is desirable, in order that the number of measurements may be few as possible, and the chance of error reduced. The large theodolite used in the measurement of angles has a thirty-inch circle divided to five minutes, and reading by the microscopes to single seconds. The telescope is of great power and partly suppported by springs within the upright columns, which bear the axis to relieve the bearings from friction. The weight of the upper part is to a considerable extent borne by friction rollers, which, taking the weight from the vertical axis, allow a very easy horizontal motion. This fine theodolite was designed by Mr. Hassler and made by Troughton & Simms, of London. There are many causes of slight error even with the best instruments in measuring an angle. Indeed, it is not possible to measure an angle with absolute correctness; but by multiplying the observations the error is reduced to a very small amount, and mathematicians can tell with certainty what the probable error will be from any number of observations. With the large theodolite above mentioned the probable error of a single measurement of an angle is about one and one-fourth seconds, and the mean of thirty measurements, the usual number made, about one-fourth of a second.

In order to measure exactly an angle between two points these points must be very closely defined. For short distances and ordinary work the signal employed by the Coast Survey is a cone of tin fastened on top of a pole; but for the larger triangles and for long distances an instrument called a heliotrope is used. This consists of a small mirror so mounted with a telescope that the reflection of the sun may be thrown in any desired direction. This reflection will often be seen eighty or ninety miles away when the outlines of mountains are entirely invisible on account of haze. The heliotrope is also used for telegraphic com-

munication; as by passing the hand rapidly in front of it the reflection is for a moment cut off, and a code of signals made by a combination of short and long flashes has been found sufficient for transmitting messages.

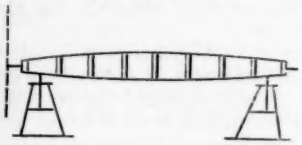
By what has preceded it will be seen that every thing in the Primary Triangulation depends upon the accuracy with which the Base Line is measured. Now, while we can easily measure an angle over a hundred times, if necessary to ensure accuracy, we cannot repeat so many times the measurement of a line without consuming unwarrantable time. Again, as the base which may be ten or twelve miles long is measured with a bar not more then twenty feet in length; if the bar is not exactly correct we shall multiply the error, say three thousand times. Thus it is that the correct measurement of the base line is an object of so much importance, and that the construction of the apparatus calls for all the skill both of the designer and the maker. A simple iron bar may be used for the measurement of distances, but such a bar is affected to a greater or less extent by heat, and although we may keep a record of the temperature, the thermometer becomes heated much sooner than the bar, and thus does not give the correct allowance to be made for the expansion of the metal. To overcome this difficulty the compensation obtained by combining two different metals may be employed, but we shall still make an error, as different metals do not undergo equal changes of temperature in equal times, on account of the different absorbing powers of their surfaces, their different powers of conducting heat from the surface to the interior of the mass and the difference in the total quantity of heat which they can take up, or their specific heats. The same coating of varnish upon both bars will give them equal absorbing powers; and by so arranging the sections of the two bars that while the amount of surface is the same the masses shall be inversely as the specific heats, a small allowance being also made for their different conducting rates, a system is formed which not only retains the same length at all temperatures, but what is no less important, during all changes of temperature.

We give in Fig. 3 a sketch, half full size, showing one end of the base apparatus as finally arranged for use on the Coast Survey. A bar of brass and a bar of iron, each about twenty feet long,



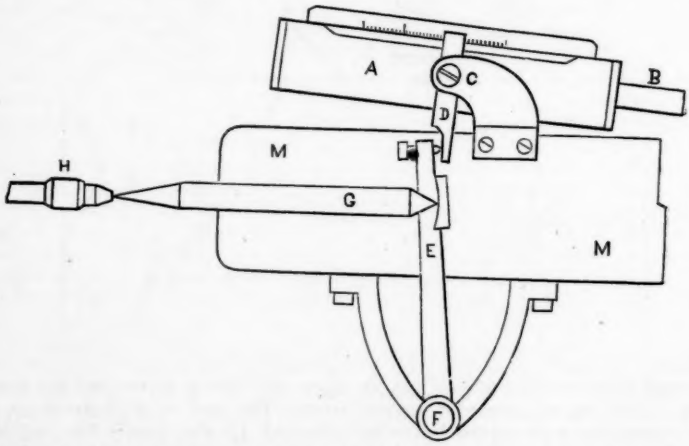
are fastened together at one end, but at all other points are unconnected, except that the upper one rests on the lower by means of little rollers. Thus both bars are free to expand at their own special rates. In Fig. 3 the free ends of the bars are represented by A and B, the upper one being of iron and the lower of brass. The end of a short lever, C, is attached to the lower bar, while the upper bar presses against it at the point D. A movement of the upper end of the lever is communicated to the small rod E, the square point of which is the

end of the apparatus. If now we suppose the bar A to remain stationary while B expands, it is plain that the point of the rod would be drawn back to the position shown in F. If A expanded while B remained still, the point would be pushed ahead to the position G. If both bars expanded equally the whole apparatus would be simply moved ahead. But if the expansion of the two bars is proportioned to the two arms of the lever, the expansion of the upper bar will move the point just as much ahead as the expansion of the lower one will draw it back. The point will thus remain *on the line*, as at H, under all changes of temperature. These two bars are supported from a stiff rib of iron, and very carefully guarded from chance of damage in transportation, the whole being enclosed in a spar shaped covering which serves as a protection from the sun and weather, making in all a shape like that shown in Fig. 4, where one set



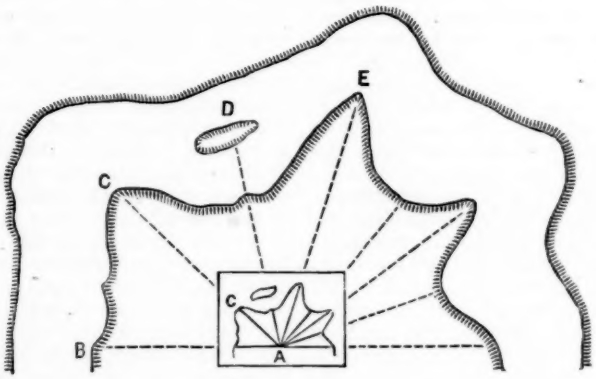
of bars with its covering is seen supported upon two trestles. To measure a base in Fig. 3. If now we move the bar M by a delicate screw towards H, the pressure of G against the lever E will move the lower end of the short lever D towards the right and will raise the weight at B. If we carry this operation

we require two sets of these bars. The back end of the first is brought directly over the starting point and carefully leveled and alligned. The back end of the second is then adjusted exactly to the front end of the first. The first is then carried to the front of the second, the back end of the first being adjusted to the front end of the second, and thus the operation continues, each set of bars being in turn moved to the front. The arrangements by which the two sets of bars are brought not only into exact contact, but always into contact with exactly the same force, is not less ingenious than the contrivance for compensation already described. The principal feature of this device is shown in Fig. 5, though in order to convey the idea clearly we have deviated somewhat from the exact form and have omitted several of the details. A short metallic bar, M M, is attached to the back end of the base apparatus, carrying a small sliding rod, G, terminating with an agate knife edge at the left hand end, while the right hand end bears against a small curved surface attached to the lever, E, turning on a pin at F. The upper end of this lever bears against the short lever, D, turning on the trunnion, C, and carrying the spirit-level, A, which is loaded at one end with the weight, B. H is the forward end of the rod shown



on until the bubble stands in the middle of the level, which may be exactly determined by the finely divided scale on top of the tube, the two rods will be in contact with a certain force. We have thus at each new position of the bars only to bring them together with force sufficient to move the bubble to the middle of the level, and the force of contact will always be the same. This exceedingly simple but effective contrivance may be seen fully illustrated in the Coast Survey report for 1854. So perfect is the above apparatus, and so skillful have the operators become, that after the ground has been prepared and every thing made ready, no less than a mile has frequently been measured in a single day, and with such extreme accuracy that the probable error is estimated to be no more than *the fiftieth of an inch.* At Bodie's Island, in North Carolina, a base line six and three-fourths miles long was measured in ten working days with a total probable error of less than one-tenth of an inch; and the correctness of the supposed error has frequently been proved by the remeasurement of a line. The place selected for a base is one which is quite or nearly level, or one which can without much expense be made so, though the base apparatus is so arranged as to measure equally well upon an incline of as much as three degrees.

The most prominent points along the the coast being accurately fixed by the Primary Triangulation, are used as the starting points for the determination of a secondary series of stations nearer to the shore, and these again for points nearer to the water line, and from the last of these points the shore line itself, and the topography in detail are drawn in by means of the Plane Table, an instrument which though long known had never been so perfected in this country as to be of much service until in the hands of the Coast Survey it has become an appliance well suited to terminate the long series of operations commencing with the Primary Triangulation. The use of this instrument will be well understood by reference to Fig. 6. Suppose that we have the river B C D E, of which it is required to map the shore line. At any convenient point, as A, we place upon the ground a plain rectangular board supported upon a tripod. A sheet of paper is fastened on top of the table,



and on this sheet a point A is marked so as to be directly over the point A on the ground. Next, lay on the table a ruler, one end being placed against the point A, and the other directed to any point on the ground, as B, which it is desired to put upon the map. Draw a line along the edge of the ruler. This line on the paper has the same direction as the real line upon the ground. In the same way direct the ruler to each point in succession the position of which it is desired to fix, and draw the correspondent lines A C, etc. If now we knew the distances from A to each of the points B, C, D, E on the ground, and laid off those dis-

tances by scale on the paper, and through the points thus obtained drew the irregular line, we should evidently have a facsimile of the actual shore line. These distances might, of course, be obtained by measurement, but there is a mode at once more correct and very much more rapid. Instead of a simple ruler we employ a brass bar on which is mounted a telescope, the centre line of which is exactly over, and parallel with, the edge of the bar, so that on looking through the telescope we look much more exactly in the direction of the edge of the ruler than we could otherwise. If we should look through the telescope we should see a fine vertical hair crossing the field of the glass, and also a series of three equi-distant parallel horizontal hairs. If now we should hold up a rod in a vertical position at any distance from the telescope a certain part of that rod would be included between the upper and the lower horizontal hairs. If we moved the rod twice as far off, twice as much of its length would be included by the hairs. This rod is divided into equal parts by figures painted in red and black, so as to be easily read through the telescope at considerable distances. Knowing by trial the number of divisions covered by the hairs for different distances, we tell at once by looking through the telescope, by the number of divisions covered, the distance of the rod from the observer. If now we send an assistant with the rod (telemeter) to each point in succession A, B, C, etc., we know precisely the distances which laid off by scale on the paper enable us to trace the shore line. The great advantage of the Plane Table method is speed and accuracy; for while the rodman is passing from A to B the assistant at the Table is laying off the length of the first line on the paper. By this method all obstacles to chaining are avoided, irregularities in the ground being no impediment, and indeed with two men, one on each side of a river, both shores may be sketched in at the same time to a degree of accuracy and with an amount of detail altogether unknown to the common methods of surveying, to say nothing of the fact that all chances of error in note taking are avoided, and that when the field work is done the plan is also complete; and not only is the outline thus traced, but all of the buildings, land boundaries, and the minutest details of topography are filled in with the utmost perfection, as may be shown by reference to the published charts. Thus, by means of the Primary Triangulation, Secondary Triangulation, and Plane Table, we obtain a minutely exact outline of the coast both in its general form and in its smallest parts, every most insignificant detail being shown exactly on the paper.

The shore line being correctly mapped, we are in condition to commence the hydrographic survey. This consists in making a sufficient number of soundings to show correctly the shape of the bottom, to fix precisely the position of all sunken ledges, bars, reefs, and shoals, to determine the nature of the material, whether rock, sand, gravel, mud, or clay, to detect all currents, the set of the tides, as influenced by the shape of the channels, and all else that can make the route to be followed by ships as plainly known to the sailor as a road upon the land is to a traveler. The exact position of a boat from which a sounding is made is easily found by reference to two fixed points upon the land. The sounding lead is so arranged as to bring up a specimen of the material when it is in any way soft, which, when desirable, is put into a small vial and so registered as to agree with the map. Vast numbers of these vials may be seen in the offices of the Coast Survey, carefully arranged, so that at any future time changes may be detected in the quality of the submarine deposit. Such changes, when closely studied, will point to their origin, and thus to the means of preserving the channel. It is well known that the peninsular of Sandy Hook in 1855 was steadily growing to the northward into the main ship channel into New York Harbor. A spot north of the Hook, where formerly there were forty feet of water, in less than ten years was nearly bare at low tide. Within a century this point has advanced nearly a mile. A careful study of the locality by the Coast Survey has detected the precise movements of the various currents, and shown just how the sediments are deposited, and whence they were derived, and thus pointed out the steps to be taken for maintaining an

open channel. The immense amount of labor expended in the hydrographic part of the survey may be understood by a glance at any of the published charts. The number of soundings thus far made has reached about eight millions. One hundred and forty shoals and reefs and fifty important channels not before known have been discovered, and accurately located, and the position of many hundred isolated rocks and ledges correctly represented upon the charts.

The field work being completed, the work of computing, digesting, and arranging the results, as well as the drawing and engraving, is done in the offices at Washington. And here, too, the Coast Survey has made a most important improvement, viz.—in the application of photography to the reduction of maps, by which the utmost accuracy and fidelity to the original are secured with speed and economy.

The designing and construction of the various instruments have also received a great deal of attention, the result of which may be seen in the splendid work of Wurdemann, which is unsurpassed by that of any maker in the world. Indeed, some of the new patterns of field instruments have been sent to Europe for geodetic purposes, being found better adapted to such work than any others in use.

With regard to the charts, nothing but an examination of these admirable sheets can convey an idea of the amount of labor and skill involved in their preparation. Every natural feature both on land and beneath the water is shown, with the position and description of lights, beacons, buoys, and signals of every kind, the course of the channels and character of the bottom, and minute sailing directions for entering harbors, aided by marginal landscape sketches, showing the general appearance of the shore from different points of approach, all of which can be appreciated only by those whose needs have taught them the value of a sure guide which shall never fail in summer or winter, by day or by night, in sunshine or in storm.

Besides its own special work, the Coast Survey has rendered the most important services to almost every department of science and art. Its discussions of the tides, winds, and ocean currents, its exploration of the Gulf Stream, its observations upon the rise and fall of coast lines, its exhaustive investigations of the complex phenomena of terrestial magnetism, have all served to augment immensely our knowledge of the physics of the globe. Its magnificent triangulation has furnished accurate base lines for state surveys and for geodetic operations in all parts of the country. The Department has also been exceedingly serviceable in supplying a great variety of valuable information to private investigations, to learned institutions, and to officers of public works, and upon proper occasions both men and instruments are freely lent for aiding any scientific operations in any part of the country.

Probably the most remarkable result obtained by the Primary Triangulation, certainly one which shows the extreme accuracy of the work, is the evidence obtained as to the figure of the earth. In order to represent correctly on a map the work done upon the ground, the latitude and longitude of the several points are required. When these latitudes are found by astronomical observation, their position is shown to be not exactly the same as when determined by the geodetic work. These "station errors," as they have been termed, are found after careful examination to arise from the fact that certain irregularities exist both in the figure and in the density of the earth; and wonderful to relate, there appears to be a close connection between the amount of this "station error" and the amount of gelogical disturbance to which the rocks in the different sections have been subjected.

Another most marked advance in science due to the Coast Survey is the electro-magnetic method of determining longitude. The latitude of a place is obtained with comparative ease, but correctly to determine longitude has always been a difficult operation. By the improvements introduced by the Coast Survey longitude is now as accurately determined as latitude, and this new mode, known as "The American method," and which has been introduced and highly approved in Europe, has justly been pronounced "one of the greatest improvements in practical astronomy known to the history of the

science, enabling the observer to do in a given time quadruple the work possible without it with nearly quadruple accuracy."

Among the various instruments, which in the hands of the Coast Survey have been made of especial value, is the zenith telescope. It is justly regarded both on account of its facility for use and the precision of its results as by far the most simple and effective instrument known for the determination of latitude, for which purpose it was first employed by the late Captain Andrew Talcott, of the United States Engineers. More recently it has been also employed for the determination of time. The accuracy of this instrument consists in measuring very small *differences* of zenith distances, instead of *absolute* zenith distances. By means of the micrometer an arc of less than one-twentieth of a second is measured, and the probable error of a single observation is only from three to five-tenths of a second.

The history of this great national undertaking may be thus briefly sketched: In 1806 (singularly enough the very year in which Prof. Bache was born), a survey of the coast was suggested to Mr. Jefferson. In 1807, Congress passed an act authorizing a survey to be made, in which the islands, shoals and places of anchorage within twenty leagues of the shore, with the courses and distances of capes and head lands, were to be represented upon accurately made charts, and Mr. F. R. Hassler, a distinguished man of science, who had been engaged upon the triangulation of the Swiss Canton of Berne, was appointed to superintend the work. In 1811, Mr. Hassler proceeded to Europe to obtain the necessary instruments, but on account of the troubled condition of the country at that time, and for several years afterwards, he did not return until 1816. The following year work was commenced in the neighborhood of New York, but on account of the difficulty of obtaining funds from Congress the work was suspended shortly afterwards, and in 1818 the law authorizing the survey was repealed. From 1819 to 1832, surveys of certain parts of the coast were made by the Navy Department. The results thus obtained, however, were so far from being satisfactory that, in 1828, the Secretary of the Navy pronounced the charts thus made as expensive and unsafe, and recommended a more systematic plan of operation. In 1832 the Coast Survey was therefore commenced anew, and again put in charge of Mr. Hassler, who continued to direct its operation until his death in 1843. Under his management the work was organized, instruments designed and made, assistants trained, and the public made acquainted to some extent with the nature and importance of the undertaking. His triangulation fixed the position of some twelve hundred stations, embracing the coast from Rhode Island to Chesapeake Bay, while the Topography and Hydrography were well advanced. "Mr. Hassler," says one who fully understood his character, "was a man of high attainments and ability, whose scientific management of the work which he had himself initiated had won universal approbation. He had emigrated to this country from Switzerland at the beginning of the century, and had brought with him ideas of scientific accuracy and thoroughness which the public mind in America was not yet sufficiently enlightened to appreciate or even to understand. He gave to the Survey the chief energies of his life, and undeterred by its suspension for fifteen years, resumed its prosecution, when permitted, anew with the same zeal which had marked its inception. On the other hand, he was a man of great eccentricity of manner, and not endowed with administrative ability. At the time of his death, the condition of the Coast Survey was anomalous and Ishmaelitish. Every man's hand was against his neighbor. The Secretary of the Treasury was the real head of the Survey, and the principal assistants reported directly to him and not to Mr. Hassler." In brief, while under a European Government, Mr. Hassler would have been all that was desired for his position, under the Government of this country he lacked just what his successor possessed in so remarkable a degree, wonderful executive power, and the ability of securing the thorough recognition of the importance of the work from Congress and from the people, and of inspiring them with the utmost confidence in his management.

The appointment of Prof. Bache brings

us to the most important and interesting period in the history of the Coast Survey. This eminent man was born in Philadelphia in 1806, being maternally a grandson of Benjamin Franklin. He entered West Point at fifteen years of age, and graduated in 1825, first in a class of extraordinary ability, and what is remarkable, having never in his four years' course received a single demerit. He remained after graduating for a short time as an assistant to Prof. Mahan, and afterwards served as an assistant to Colonel Totten in the construction of Fort Adams at Newport. In 1828 he was appointed Professor of Natural Philosophy in the University of Pennsylvania, at Philadelphia, where he remained seven years. In 1836 he was made President of Girard College, and visited Europe for the purpose of examining the principal educational institutions below the grade of universities, and in 1838 prepared an elaborate report of over six hundred pages, being the result of a thorough examination of two hundred and eighty several schools in Great Britain, France, Switzerland, Holland, Italy, and the German States. The opening of Girard College being so long delayed, he assumed the position of Principal of the High School and Superintendent of Public Schools in Philadelphia, in which position he rendered inestimable services to his native city. In 1842 he was again appointed to his old position in the University of Pennsylvania, which he held until November, 1843, when at the unanimous call of the various colleges, learned societies, and men of science of America, endorsed by such names as Humboldt and Arago in Europe, he was at the age of thirty-seven years appointed Superintendent of the United States Coast Survey, a position for which by natural endowments and extraordinary scientific attainments he was so admirably fitted, and which he retained until his death, which occurred at Newport in 1867.

From this time the work was immensely expanded and driven on with the most untiring activity. In order that the progress might the sooner meet the pressing and rapidly increasing demands of commerce, and that the truest economy might be secured, the coast was divided into eleven different sections, each having as nearly as might be the same length of shore, and each having its own base line, but the whole forming a single system of triangles reaching from Maine to Texas, each division thus verifying the next. By this system, according to the report of the Secretary of Treasury, a double expenditure produced a threefold result, the same parties working in the North during the summer and in the South during the winter.

The extent of the work thus brought into one system may be thus briefly stated:

	Length in miles of general coast line.	Length of the shore line.
Atlantic Coast	3,036	14,723
Gulf Coast	2,162	10,406
Pacific Coast	1,866	4,252
	7,064	29,381

If we suppose the whole time necessary for the completion of the work to extend from 1840 to 1880, or forty years, and the annual expense to be five hundred thousand dollars, we shall have paid for our whole thirty thousand miles of shore line twenty millions of dollars, a sum greatly less than any other government has paid for the like amount of work. It has been stated, and correctly, that the annual cost of the Coast Survey never exceeded the cost of a first-class steamer. Certainly the whole cost from the commencement has not surpassed the value of a dozen first-class Indiaman with their cargoes.

"The rule of Professor Bache in the work of the Coast Survey," says his memorialist, "was that all of the scientific work should be executed in the most thorough and accurate manner which the resources of science and art would permit. He never shunned a tenfold labor if it was to be repaid by a double precision, accepting the great principle which prescribes a higher rate of effort as we climb to higher degrees of refinement." Under his guidance for twenty-four years the best scientific talent of the country was drawn into the service of the Coast Survey. The nineteen quarto volumes of the Coast Survey Reports from 1852 to 1870, containing no less than six thousand pages and eight hundred plates, besides one hundred and twenty-three scientific papers presented to different associations

from 1829 to 1864, with his annual reports as Superintendent of Weights and Measures, and twenty-one several reports upon various harbors, the last made jointly with Messrs. Davis and Totten, all testify to the immense activity of the man. Not the least laborious part of his work, but certainly the least agreeable, was the perpetual exertion necessary to counteract the attempts of evil-minded people at Washington. Hardly a session of Congress passed in which personal spite, local jealousy, prejudice, or envy, did not show its hundred-headed "bad-visaged front," striving always to sap the foundations of the noble structure which was steadily rising to the public view, until at last so virulent were these attacks and so apparent their animus that the learned societies, chambers of trade and commerce, insurance companies, and private individuals, all over the country united in one grand protest against interference.

The opinions of European savans in regard to the Coast Survey and its director, may be gathered from very numerous letters from such men as Arago, Humboldt, Admiral Smyth, and, lastly, from Sir Roderick Murchison, who in presenting the Victoria Gold Medal of the Royal Geographical Society of London, to Prof. Bache, remarks, that whether we regard the scientific skill and zeal of the operators, the perfection of the instruments, or the able manner in which the Superintendent has enlisted all modern improvements into his service, all must agree that the Trigonometrical Survey of the United States stands without a superior."

When it is considered that the Coast Survey organization embraces not only civilians, but at the same time officers of both Army and Navy, it will be seen that the chief who could so direct these somewhat discordant elements as to produce a maximum of progress with a minimum of internal dissatisfaction must be no ordinary man. We may, therefore, well understand and believe the truth contained in the following eulogistic words of his memorialist:

"It was not merely by his ardent love of science, and his disinterested devotion to her welfare that he accomplished so much. His fertility of device, unconquerable assiduity, large policy, generous impulses, patriotic devotion, might well have co-existed without yielding such fruits in the development of the Coast Survey, or such a mighty power for good in the promotion of science throughout the United States. More was needed than these; far more than these he possessed. The greatest of all his mental gifts, or attainments, were his marvelous knowledge of human nature and his unrivaled skill in using it. He had studied men as he would study physical phenomena. To a faculty of persuading the most obstinate, of soothing the most irritable, of encouraging the most disheartened; to a power of stimulating the most indolent, controlling the impulsive, winning over opponents by the charm of his manner, and confirming friends by the truthfulness and sincerity of his nature, he added that rare endowment, which imbued others unconsciously with his own zeal. His companionship evoked latent aspirations, and pointed to noble aims. He knew the secret of obtaining work from his subordinates, by doing more than they did. By no act of his life did he ever curtail any man's means of usefulness, or fail, whenever it was within his power, to render available whatever abilities might be disclosed. Justice and even-handed firmness controlled his action. Cautious in plan, bold in action, as courteous to his assistants and as considerate of his subordinates as though they had been his superiors, ever as open to conviction as to argument—such was his noble character. The progress of education, the development of scientific research, the extent of scientific discovery, the growth of the arts and the spread of commerce have all been greater in America because he has lived."

It is almost impossible to do justice to the chief of an important undertaking without doing a seeming injustice to his associates and assistants. Many of Napoleon's Marshals were great men, but Napoleon's greatness overshadowed them all. Great as Prof. Bache was, he never could have accomplished the vast work of the Coast Survey unaided. Without the labor of his assistants—most of whom are yet active workers in the field—the admirable results which we now see would never have been reached, nor should we have had the declaration from one of England's foremost men of sci-

ence, that "The Coast Survey of the United States is one of the most perfect exemplifications of applied science of modern times."

DOMESTIC MOTORS.

From "The Engineer."

Let it not be thought that the subject dealt with in this article is too insignificant to deserve the attention of mechanical engineers; nothing which can add to the comfort of a civilized community is too trifling to claim the exercise of the talent for invention. Who will supply a want long felt, and give the world a really good domestic motor, an engine of some kind which will drive any or all of the machines now common in almost every household? At first sight it would appear that there can be no great difficulty in producing a small apparatus which would suffice to drive a sewing machine, a knife cleaner, or a washing machine; but a little examination of the subject will show that it is rather more complex than appears at first sight. Attempts have been made to solve the problem, but we question if those who have made these attempts have gone quite the right way to work. As the conditions are not easy of fulfillment, we shall first state these conditions, and then indicate the direction which inventors should take to satisfy them. In the first place, then, a domestic motor must be safe—that is, it must be absolutely free from risk of explosion or fire. In the second place, it must be generally applicable. In the third, it must not be likely to get out of order. Fourthly, it must be perfectly under control, and require no special skill to manage it. Fifthly, it must be cleanly in its operation; and lastly, it must be cheap. One or two minor requirements might be stated, but we believe we have enumerated all that are essential. It is obvious that what applies to the production of motive power in the abstract will apply to all motive power engines, small or great. We cannot create power, and so, whether we want to propel an ocean steamship or to drive a sewing machine, we must call in some of the forces of nature to aid us. Before going further, therefore, we may at once dismiss all such schemes as the winding up of springs or weights to produce motion. The power to be thus obtained must first be got by the exercise of manual labor, and it would be better to apply this labor directly to the machine to be driven than indirectly to springs or weights, for reasons very well understood by engineers, at all events. The forces of nature available for our purpose are gravity, heat and electricity. They can be applied in various ways as follows: Firstly, gravity is available under certain conditions in the fall of a body of water; heat can be utilized by a steam, hot air, or gas engine; and electricity can be made to serve our purpose by the aid of the magnet. From this list our domestic motor must be selected. It remains to be considered which is most like to serve our purpose.

Where a constant supply of water under pressure is available, it would seem that nothing is so suitable for driving a domestic motor. It is not beyond the skill of the engineer to construct a little turbine, for example, which could be fixed in a neat case against, or even sunk into, the wall of a drawing-room, and to which a pipe, concealed like a gas pipe, behind the wall-paper, could be laid from the cistern on top of the house, while the discharge pipe could, similarly concealed, be led to the most convenient place where it might be discharged into a drain. The space occupied by a little turbine of this kind would be quite insignificant. The covering might be rendered very ornamental, and the power could be taken off by a small belt or gut line. In this way every drawing-room or boudoir might contain a motor available at any time to drive a sewing machine. Its operation would be quite silent, danger there would be none, and to start or stop it would be as simple an operation as turning gas on or off. If necessary, the same plan might be carried out to drive a washing machine,

knife cleaner, &c., in the basement of a house, a somewhat larger and coarser machine being used. But in no case would the turbine take up much room or use a great deal of water—about one-fifth of a horse-power is the maximum that would be required. This would be obtained by the expenditure of about 2,000 gallons of water per hour under a head of 20 feet, or half that quantity under a head of 40 feet. This would practically represent the work of a couple of strong men. To drive a sewing machine, of course very much less would suffice. Where water under a sufficient head is available in the requisite volume nothing better than the arrangement we have sketched out can be desired. It is evident, however, that in London, at all events, and indeed in most large cities, water cannot be had in this way in sufficient quantities, and we must reluctantly reject the turbine as not fulfilling all the requirements of an almost universally applicable domestic motor.

Steam may be used for the required purpose, and an apparently not unsuccessful attempt is now being made by a London firm to introduce miniature steam engines for driving sewing machines. The little engines are on the oscillating principle, are extremely simple, and well made. Steam is supplied by little vertical boilers, heated by a Bunsen burner or ring. No chimney is required, and the exhaust steam is carried off by india-rubber pipes. Although the pressure used is low and the boilers small, the arrangement cannot be pronounced quite free from danger; and the heat and smell inseparable from the use of steam, and the difficulty of satisfactorily disposing of the exhaust, must always tell against the popularity of this, or any other form of steam engine, as a motor suitable for drawing-room use, although it would, no doubt, prove serviceable in tailoring establishments, and other places where a considerable number of sewing machines have to be worked; and it would probably do good service in small laundries. It will be seen, then, that neither water nor steam is likely to supply what we want. We may take electricity out of its order, to dismiss it at once, as being too costly, delicate, and troublesome to satisfy our requirements. Nothing is left, then, as likely to furnish motive power, but hot-air engines, gas engines, or petroleum engines. Hitherto hot-air engines have not been successful; but this is due to causes which would hardly operate in the case which we are considering. It ought to be possible to produce a little hot-air engine which would drive a sewing machine silently and without trouble, the heat being supplied by a gas jet. The little engine need not weigh more than a few pounds; economy would not be sought, and the regenerator could be wholly left out. The gas could be taken from the gaselier overhead by an india-rubber tube, and as it would not be necessary to wait for a fire to burn up, the machine should be ready to operate in five minutes after the gas was lit. There would be little that was objectionable about the machine. It would be perfectly safe, easily managed, and the hot air discharged would be small in quantity, and readily disposed of by the ordinary ventilation of the apartment. Larger machines, but still small, could be used for heavier domestic work. We are disposed to regard the hot-air engine as presenting an excellent solution of the problem; but something still better may, perhaps, be found in the gas engine. Lenoir's engine, apart from the electrical apparatus, which is not essential, we need hardly say, was simple enough, and we see no difficulty in constructiug little engines on this principle modified, of, say, one-tenth of a horse-power, which might be elegant in design, simple, and easily managed. Petroleum engines the world knows too little about at present to enable us to present any opinion on their suitability for the required purpose; but while gas is available, as it now is, in every town and in many country houses, we see no reason for abandoning it in favor of petroleum.

One point remains to be dealt with, namely, the cost of a domestic motor; this must be small. It should not much exceed £5, if a large sale is expected, and we venture to think that the very magnitude of the sale which would be secured for a really satisfactory domestic motor would enable the price to be kept within the limits we have named. It may be argued that to produce an efficient motor, however small, for £5 is

absurd, but we cannot agree to this. A steam engine, for example, is by no means so complex as a sewing machine, but the latter can be sold for £5, allowing a good margin for profit. Not many years since we heard it argued that it was impossible to produce a lawn mower, which would be of use, for less than £5. Excellent little lawn mowers are now sold literally by the thousand for 25s. If a good design is once obtained every portion of the domestic motor might be turned out by machinery, and fitting reduced to a minimum. No engineer, it would seem, really knows what he can do till he tries, and we are certain that by trying, not only may a motor be supplied, but that it can be sold, if not for £5, for something very near that sum.

Whether a sufficient demand would exist to make it worth while to invest capital in the requisite plant for turning out domestic motors by the thousand, is a question which we cannot answer decidedly, nor can anyone else. If we reason by analogy, it would appear that the same laws would apply to such machines as to several others. The first man who made portable engines gave up the business after he had turned out twelve, because, he argued, that more than a dozen portable engines could not possibly be wanted in England. When the sewing machine was first produced it was held that the demand for it must always be limited. Sewing machines are now made by the million. We might cite a great many other instances to prove that the possibility of obtaining a given machine appears to create a demand for it, and we think this would apply in the case of the little engines with which we are dealing. However, it is perhaps premature to speak of the possible demand for a machine which does not as yet exist; although we have no doubt that it is practicable to produce it, some exercise of inventive ability will be needed in the production.

NAVAL GREAT GUNS AND GUNNERY.

From "Iron"

A PAPER on this subject was read recently by Mr. J. Scott Russell at the Royal United Service Institution. Mr. Russell said: "What I propose to lay before you to-night is the special question—What should be our new navel gun, to take the place of my favorite old 8-inch guns? The two important points I first want you to settle are these: What weight of gun can you accept as the (handleable weight) manageable weight of gun? Next, what work do you want the gun and its projectile to do? If you settle these two leading points, I think I can see how all the rest can be done. To secure most execution at moderate and sure range seems to me the essential character of naval gunnery as distinguished from land gunnery. If that be agreed, I now proceed to see how we can get most use for that end out of our 12-ton gun. I say then at once that you will get much more practical good out of your 12-ton gun by giving it a large bore of 12 inches than a smaller bore of 8½ inches. In a 12-inch bore the powder-power propelling the shot is 144. In an 8½-inch bore the propelling power is 72. Or the work done by the 12-inch bore is double the 8½-inch bore. For the present I confine myself to this statement; I will prove it later on. Next, I will take the question, how shall we turn this double propelling question to account? We have two ways, to send out a heavier shot, or to send out the same shot with higher speed. Now, in regard to weight of shot, I may observe that as you have fixed weight of gun I shall consider the weight of shot as fixed also. Your gun weighs 12 tons, that is, 240 cwt. Now, according to the best practice in all countries, the normal shot is 1 lb. of shot to each 112 lb. of gun. This gives for the 12-ton gun 240, or 12-ton gun (240 cwt.) 240 lb. shot. Taking, then, 240 lb. shot in 8½-inch gun, and 240 lb. shot in 12-inch gun, we have double the powder-power propelling the same shot; or double the propelling force pushing forward the base of the shot. Therefore, the same weight of shot will be discharged with much higher speed. Now speed of shot is, as you know, a much more effectual means of destruction and penetration than mere weight; double weight of shot has double pene-

trating power; double speed of shot has fourfold penetrating power. The larger bore has, therefore, the great advantage of giving higher speed of shot and greater penetrating power. Double weight gives double destruction. Double speed gives fourfold destruction. The next element of efficiency is the power of the hollow shot as an explosive shell. I need not prove that with the same weight of piercing shell, the larger bore admits of much larger explosive effect of the shell. Shell has much larger capacity for explosive charge. Thus, then, in all these ways greater initial speed, greater destroying power, greater explosive effect, the large bore 12-ton gun is more effectual for naval use than the smaller bore. So much for the power of the larger gun for more work. I now proceed to show how, by wise arrangement, this larger bore gun of 12 tons may have more endurance than the small bore gun also of 12 tons. I shall be told at once that it is quite true that my large bore has greater propelling power on the shot than my small bore; but that the powder in my large bore has greater bursting power on the gun barrel than in the small bore. This is quite true, but it is true in quite different proportions. The propelling power is as 72 to 144. The bursting power is as 102 to 144.

This gives a clear balance in favor of the large bore of 144 to 102, or of 42 per cent. gain. Propelling powers 72 to 144. Bursting powers 102 to 144. The larger bore is the more lasting gun. Thinner metal, 21 to 24; more effective distribution, 26 to 18; gain, 54 to 43. The next question is mode of rifling. On this I have merely to say that I have always been the consistent advocate of accelerating twist for small bore guns with common powder charges. But for large guns with new and well-regulated powder charge, I am of the opposite opinion. For large guns, with regulated powder charge, we must lay aside accelerating twist and come to uniform twist. My reasons are two. First, accelerating twist injures large guns; second, it is rendered quite unnecessary with a regulated powder charge. What we want is not slow burning powder, nor quick burning powder; but powder-charges that will burn quick when we want it quick, and slow when we want it slow. Or what I call a regulated charge, slow burning of powder at first, gradually growing quicker and quickest at last. Now, if you can get that done, your guns will last longer than they have ever done, your shot will go further, and faster, and steadier than they have ever done, and your whole work will be better done than ever. We now meet face to face the next question, Have we got such regulated powder charge as I speak of? The answer is, No, very much the reverse; and then the next question, Can we get them? I answer, "Say you wish it," and you will get it. As to the material of which our naval gun should be made, there need now be no doubt. Steel and iron can now be made of any required quality, and nearly any quantity in one piece I know that the 12-ton 12-inch gun we have been discussing can be made of Whitworth's condensed tough, powerful steel, in two concentric tubes or cylinders, an outer and an inner tube. I dare say that our engineers at Woolwich will be able to make you the outer body of that gun in one piece of wrought iron, with an inner single tube of Frith's steel. By and by, if you desire it, the gun may be one whole, but at present I prefer to have it in two layers, outer and inner, but each extending the whole length, and not in patches. Cheaper shells might be good enough for practice, but I consider that when you come within shot range of your enemy, there is no shell, however costly, that should be reckoned "too good" for him. In short, the most effective would be really the cheapest. In regard to gunnery and gun carriages, I think that when you have resolved to adopt breech-loading matters are simplified very much. I think the existing naval gun-carriage, as designed by Captain Scott, is an extremely good one. I also am of opinion that for certain special ships of war the gun-carriage of Major Moncrieff offers very important advantages in use, and facilities in application. But the most important of all gun carriages is the ship herself, which carries the great guns we are now discussing. Unless the ship herself possesses all the qualities of a handy, quick, steady, secure gun-carriage, nothing we can put on board of her will enable her to win a battle at sea.

RECLAMATION OF THE SUBMERSIBLE LANDS OF THE MISSISSIPPI VALLEY.

By J. P. FRIZELL.

Written for Van Nostrand's Engineering Magazine.

By an Act of Congress, approved June 22, 1874, the President of the United States was authorized and directed to appoint a Commission "To make a full report to the President of the best system for the permanent reclamation and redemption of said alluvial basin from inundation."

The Commission consisted of three engineer officers, viz. :

Major G. R. Warren.
Major H. L. Abbott.
Captain W. H. H. Benyaurd.

And two civil engineers "eminent in their profession," viz. :

Jackson E. Sickels ; and
P. O. Hébert.

This Commission presented a report under date of January 22, 1875, in which they advert to the several methods of protection that have at different times occupied the public attention, and indicate the following as their conclusions :

The attempt to control the height of floods by cut-offs is fraught with such danger to the banks that it should never be made ; then spontaneous occurrence should even be prevented when practicable.

Division of tributaries is not thought worthy of serious consideration.

The Commission summarily condemns the project of a system of reservoirs as "chimerical.

"The "Commission is forced unwillingly to the conclusion that no assistance in reclaiming the alluvial region from overflow can judiciously be anticipated from artificial outlets. They are correct in theory, but no advantageous sites for their construction exist."

After considering some objections urged against a completed system of levees, and pronouncing them unfounded, they proceed to recommend this mode of protection. The report goes on to prescribe the height of levees for different parts of the river, with reference to the highest known flood occurring in the uncompleted state of the levees, viz. : 3 feet near the mouth of the Ohio, increasing to 7 feet at Osceola ; thence to Helena this latter height should be maintained ; thence to Island 71 gradually increasing to 10 feet, gradually diminishing to 8 feet at Napoleon ; thence to Lake Providence it must be gradually increased to 11 feet ; thence to the mouth of the Yazoo it must be gradually reduced to 6 feet, and it should thus be maintained to Natches ; thence to Red River Landing it must be gradually increased to 7 feet; thence to Baton Rouge it may be gradually reduced to 5 feet ; thence to Donaldsonville this height must be maintained. At Canolton, 4.7 feet will suffice, &c. The levees should be located at a sufficient distance from the river bank to guard against caving. An approximate estimate is presented of the cost of a completed system amounting to about 45 millions of dollars.

Upon completion of the works they propose to intrust their maintenance and care to a board of engineers or superintendents, each of whom will exercise authority in a certain district, and who will have a mutual organization with powers and functions analogous to those of the river syndicates of France and Spain. They recommend further an accurate instrumental survey of the entire alluvial region subject to overflow. It is very much to be regretted that this survey was not authorized by Congress.

Without denying the general conclusions of this Commission, I must be permitted to say that they would, in my opinion, have been entitled to more weight had the report more fully met certain grave objections to which a completed levee system is liable.

What is said of the tendency of dyked rivers to elevate their beds, is substantially a repetition of the views contained in Humphrey's and Abbott's report. It appears to me that the true source of danger is not discussed in either of these

reports. We need not ascribe to rivers dyked or undyked any tendency to elevate their bottoms or their low water surfaces. It is none the less true that a completed system of dykes does set in motion causes tending inevitably to the progressive contraction of the high water section of the river, and the progressive elevation of its flood surface.

That the deposits resulting from the overflows of the Mississippi, in its natural state, have elevated the ground in its immediate vicinity, is evident from the fact that the ground, in all cases, descends as you recede from the river; the river banks being often 10 or 15 feet higher than the swamps which lie parallel with, and at some distance from, the river. Upon the completion of the system of dykes, it is equally evident that this process must cease inside the dyke, while continuing with increased vigor outside. The exposed ground (*vorland* as it is called in Germany) is withdrawn from cultivation. Every overflow is succeeded by a rank growth of bushes and reeds whose roots hold fast the material deposited, and whose stems operate to check the water and increase the deposits of the next year. The evil is greatly aggravated if the *vorland* is protected by a low dyke as suggested in the report. In this case, at every overflow of the low dyke, the *vorland* is filled with turbid water moving with a very moderate velocity, a condition favorable to enormous deposits. I have seen, on the Mississippi, in the analogous case of a flooded coffer dam, a deposit of more than 12 inches in the course of a single flood.

The contraction of the flood water way, from these causes, tends, of course, to increase the height of the floods, and levees originally sufficiently high will require to be progressively raised and strengthened.

In swampy regions, another cause comes into operation to increase the height of floods with reference to the reclaimed ground, *i. e.* the subsidence of the latter in consequence of the better drainage permitted by the levees. Reclaimed polders in Holland usually sink one or two feet from this cause.

It is not alone with reference to the Po, as the report appears to assume, that apprehensions of gradual elevation have been entertained. Such fears have been felt with reference to the Rhine, and this not alone by speculative physicists, but by engineers specially conversant with this branch of their profession.

Hagen* considers the fact of such progressive elevation well established. He cites two papers bearing upon this point. One, a memoir presented by Blanken† to the Institute of the Netherlands in 1818, in which he shows that dyke-breaks upon the Rhine and Waal had increased in frequency, as compared with the preceding century, notwithstanding the raising and strengthening of those dykes which were then much higher than formerly. The other, a report by Rechtereu,‡ in 1830, in which he goes so far as to recommend the flooding of the country in the winter as the only means of avoiding ultimate ruin.

The Commissioners say: "The prolongation of the delta into the gulf by the aggregation of sedimentary matter is also assigned as a cause for the ultimate rise of the bed, and hence for a future necessary increase in the height of the levees. A possible secular change of this nature is quite too remote in its effects to merit attention from practical men of the present day. Simple calculation will show that hundreds of years will be required to raise the flood height at New Orleans an inch from this cause."

Here, again, it appears to me that the Commissioners have failed to note the real danger to be apprehended from changes at the mouth of the river. A passage in the physical history of the lower Rhine may be interesting in this connection. I translate from Hagen:§

"At what time the old Rhine was entirely closed, and when the numerous connections between the Waal and the Maas, either spontaneously originated or were artificially opened, is unknown. Many dyke-projects, however, were executed in the twelfth and thirteenth centuries at which time the entire existing dyke-system originated. Whether this was done in the immediate interest of agriculture, without reference to its ef-

* Handbuch der Wassenbankunst. Theil 2 Band. 3, p. 704.
† Beschouwingover de Uitsrooming der Opper Rijn en Maas-Wateren. Amsterdam, 1819.
‡ Verhandelingen over den Staat van den Rijn, de Waal, etc. Nijmegen, 1830.
§ Handb. d. Wassenbankunst. Theil 2 B. p. 428.

fect upon the regimen of the rivers, cannot now be ascertained. Certain it is that the dykes became a new cause of derangement to the rivers, and many new channels were opened by dyke-breaks. The most frightful instance of this kind was the overflow of the Waal and Maas in the South Holland Waard, or the *Bergsche Feld.* The Maas had already, in the lower part of its course, united itself with the Waal, and both, on the 18th of November, 1421, broke through the left dyke, between Woudrichem and Dortrecht, and flooding the low lands, destroyed a surface of many square* miles. The water thereby opened for itself a new mouth in the sea, through the deep and wide bay of the Beisbosch, through the Holland's deep, and through the Krammer. Seventy-two† villages were destroyed by the water together with the ground on which they stood. This devastation is only explainable upon the supposition that the sea, being put in communication with the dyked land, entered it at every flood and receded at every ebb. Thus originated the powerful currents which led to the widening and deepening of the channel. A natural consequence of this dyke-break was that the Waal now took the level of the North Sea at the Beisbosch, that is, 10 miles (about 45 English miles) from its former mouth, and its course was, thereafter, shortened by that distance. The relative fall thereby augmented, as far as the point of separation (from the Rhine), at Lobit. The rush of waters increased, and in proportion as the channel was extended and deepened, those of the Rhine, the Leck and the Issel were shoaled by the diminished velocity. This relation which promised the entire closing of the weaker arms and the ultimate reunion of the streams in a single channel, disappeared, however, and a remarkable change was allowed to develop itself in the course of some centuries. The Beisbosch was, by the sediment of the river, and possibly also by tidal action, gradually filled up, and the broad bay was replaced by a marshy region in which isolated islands already raised themselves above the ordinary level of the water. They were overgrown with grass and bushes, and were soon provided with dykes. Between them were a great number of shallow water courses, which were naturally no longer in a condition to carry off the greater part of the volume of the Rhine, and still less could the level of the sea establish itself therein. The low water-level in the Waal thus disappeared, and with it the former large (relative) fall. The Rhine and the Leck, and likewise the Merwede or lower part of the Waal, thereupon took a stronger current, and the entire volume of the Rhine resumed its course through these arms, while, in consequence of the previous diminished current, the depth therein had diminished in a remarkable degree, and they had become entirely insufficient for carrying off the waters. The streams could only be confined to their beds by raising the dykes, but they filled these to such an alarming height that not only did the natural drainage in great part fail, but the danger of dyke-breaks ever increased and the existence of many important places was continually threatened."

We see, then, that apprehensions founded upon possible changes at the mouth of the river are not so groundless as the Commissioners suppose. The completion of a system of dykes is very liable to cause changes in the course of the lower river by curasses, and these changes are liable to necessitate an increase in the height of the dykes.

I pass now to another point of most vital importance, which, strange to say, has not been touched upon, either in this report or in the very voluminous and valuable report of Humphrey's and Abbott. How is it proposed to deal with the rainfall in the reclaimed district?

In the history of the levees, thus far, this question has attained no practical significance. They have been built to meet immediate and local wants, with but slight consideration of ultimate effects consequent upon the completion of the system. They have afforded protection only to the higher grounds near the river, leaving always extensive swamps in the rear to receive and convey away their surface water. Upon the completion of the system, the swamps above Red River will no longer afford this relief. Their outlets are liable to be back-

* A square German mile is about twenty square English miles.

† Blanken. Memorie betrekkelligk den Staat der Rivieren. Utrecht, 1823, page 22.

ed up from four to ten feet above the highest flood hitherto known. The flood stage of the river lasts sometimes three or more months, during which time the alluvial districts are liable to receive a rainfall of two feet or more. Without efficient drainage, their condition will hardly be improved by the levees. In fact, extensive tracts will be liable to overflow several feet deep, which, without levees, would have been above water. Claims for protection will be urged with redoubled vehemence, claims which the Government cannot in justice disregard, the evils being of its own creation. I can conceive of no effectual remedy for these evils other than a vast establishment of steam-pumping machinery. Such an establishment is ultimately inseparable from a perfected system of levees. If the Government commits itself to the first, it cannot reasonably or justly evade the second.

Let the reader endeavor to form an idea of the cost of such an establishment, capable, for instance, of relieving a district 20,000 square miles in extent, of 12 inches of rain-water in the course of 30 days, the water to be raised 12 feet. The result is absolutely appalling. More than three times the sum assigned as the entire cost of the levees.

It is not the purpose of this communition to offer anything in the way of practical suggestion, but rather to urge the importance of a more thorough consideration of the subject than it appears to have received from this Commission. The method of protection by levees, once resolved on and undertaken by the Government, must be persevered in, however great the difficulties in their maintenance developed by time. The longer they afford protection to the country, the more important become the interests to be protected, the more deplorable results of failure, and the stronger the obligation to maintain the system. The Government should not be committed to action so momentous and irrevocable without all the light that the history of similar works can afford, lest the difficulties, now but dimly to be foreseen, should progressively acquire such strength as to become utterly overwhelming.

LIME.

From "The Builder."

Of all the materials used in construction, lime is perhaps the most important, and the following *resumé* of several series of experiments made by French engineers and others into its nature and treatment cannot fail to be acceptable.

I. *Pure or quick Lime, Oxide of Calcium*, is composed of 28.58 parts of oxygen, and 71.42 parts of calcium, a substance white in color, caustic, pulverulent, absolutely infusible in the fiercest fire, susceptible of crystallization in rhomboidal prisms, and of a burning and acrid taste; it quickly disorganizes animal substances brought into contact with it, turns syrups of violets green, and gives to turnsole the same reddish blue color as an acid.

Its specific gravity is 2.30. It dissolves in 900 or 1,000 times its weight of cold water, or in twice that quantity of boiling water. It is scarcely ever found in nature in a state of purity, except in some volcanic productions.

Brought into contact with water, it is transformed into hydrate; it gives out a quantity of heat which may amount to 300°centigrade, and is capable of igniting gunpowder; a part of the water escapes in the form of very hot vapor, slightly caustic, and a noise is produced resembling that caused by plunging red-hot iron into water; it melts or is reduced into impalpable powder, or into paste. This hydrate is *chaux amortie*, *chaux couleé*, or *chaux éteinte*, slaked lime, to distinguish it from quick or anhydrous lime.

II. *Physical Characteristics.* — When slaked, lime increases in volume; it swells according to its degree of purity, and sometimes attains a volume two or three times that of the quicklime from which it is produced. That which has

absorbed a volume of water equal to 2.60 to 3.60 for one of lime is called *chaux grasse*, or fat lime; and which has only taken up 1 to 2.30 per cent. of water, *chaux maigre*. When the latter hardens, not only in the air but under water, it is called hydraulic lime.

III. *Limestone.*—Lime is obtained for industrial purposes by the calcination of calcareous stone, a substance composed of lime and carbonic acid, and which partly dissolves in weak acid, with more or less effervescence. The quantity of lime which it is capable of yielding is in proportion to the carbonate of lime contained within it.

Pure carbonate of lime is very rare; it contains 55.98 parts of lime, and 44.02 of carbonic acid. When calcined at a high temperature, it yields pure caustic lime.

Calcareous matter is one of the most common. In nature, it is usually mixed with silica, alumina, magnesia, quartz in grains, or sand, clay, oxide of iron, manganese, bitumen, and sulphur, or pyrites. The combination of these various substances constitutes several kinds of limestone, which are subdivided into many varieties.

Mineralogists distinguish several kinds of limestone, and point out varieties of form and texture in each; but that which is important for the builder to know is, that each kind furnishes a special line different in color, density, greediness for water, and especially in its practical results when mixed with sand.

The physical characteristics of calcareous stones furnish no certain data with respect to the kind of lime they will yield, and even chemical analysis affords but approximate results. Formerly it was maintained that the hardest, heaviest, most compact, and most homogeneous stones, with the finest grain, made the best lime; it is now admitted that these characteristics are not sufficient indices of the quality of the products to be obtained from them. It is only by trials and experiments that their value can be determined. The purer the limestone, the more the lime obtained will swell; if the carbonate of lime contain foreign matter to the extent of ten or twenty per cent., the lime after being slaked will swell very little or not at all, it is poor.

IV. *Hydraulic Limestone.* — As hydraulic limestone is the most valuable on account of its peculiarity of hardening rapidly under water, it is most important to ascertain what limestone will furnish it. For a long period scientific men were not agreed as to the causes which rendered lime more or less hydraulic; some attributed this peculiar property to the presence of metallic oxides, others to a combination of silica and alumina. Smeaton, in 1756, discovered that the hardening by immersion was due to a certain quantity of clay contained in the limestone possessing that quality. MM. de Saussure, General Freussard, Berthier, and Fuchs, of Munich, have published remarkable papers on this subject, but no one has done so much for it from a scientific point of view as M. Vicat. Before his time there were not ten quarries in France in which hydraulic limestone was known to exist, but after traveling the country on foot for years, he discovered more than three hundred, and there is not a department in all France that does not owe to him the discovery of a mass of mineralogical wealth.

V. *How to recognize hydraulic Limestone.*—Hydraulic lime being produced from the mixture of carbonate of lime with clays, it is important to know the quarries in which the variety is to be found. M. Vicat recommends that the strata should be deeply sounded, as the chemical composition of the lower layers may differ sensibly from that of the layers more exposed to the influence of the atmosphere. It has been remarked in general, that limestone of a dirty grey, ashy, or bluish tint, contains much more of the argillaceous or silicious principles than that of a compact or crystalline texture. The information obtained from miners and masons is very useful; and we must not be disconcerted by failures; they arise, generally, simply from misdirection of research. M. Chateau relates that for a long time Paris obtained her hydraulic lime from Senonches, at the cost of 80 francs the cubic mètre, while the quarries of the Buttes - Montmartre, the Buttes-Chau-

mont, and Romainville, which yield limestone that produces all the varieties of hydraulic lime, remained unexplored. For the testing of limestone, M. Vicat recommends the burning first of a small quantity, and afterwards on a large scale. The difference of the weight and the value of the products will thus set all doubt at rest.

VI. *Mode of Trial.*—The method proposed by Mr. Berthier is as follows:

Crush the limestone, pass the powder through a silk-sieve and pour upon it little by little muriatic acid, or, in the absence of that, sulphuric acid, or vinegar, diluted with a small quantity of water, stirring it continually with a glass rod or a stick, and continuing the application of the acid until all effervescence ceases; evaporate the mixture with a gentle heat, and when all is reduced to a soft paste mix this up with about a pint of water and filter it; the clay, which will remain on the filter, must then be dried, either in the sun or before the fire, and weighed; or, which is better, calcine the clay to redness in an earthen or metal crucible before weighing it, then pour lime-water on the filtered solution so long as any precipitate continues to fall; collect this precipitate, which is magnesia, sometimes mixed with iron and manganese, as quickly as possible on a filter, wash it with pure water, dry it as completely as possible, and, finally, weigh it. The weight of the clay compared with that of the calcareous substance dissolved gives approximatively the rank which the mineral should fill amongst hydraulic limestones. It is important to note that after the first filtration no clay may be found, or only a mixture of fine sand with clay; in the former case, the limestone will only furnish poor lime; in the latter, the sand must be separated from the clay by washing and decantation, to ascertain the respective weight of each.

VII. *Lime-burning.*—In the burning of lime, all kinds of fuel are employed, according to the locality—wood, heather, peat, coal; coke gives excellent results, charcoal not so good, besides being very dear. The form of the kilns varies with the customs of the place, and the kind of fuel employed: it should tend to economize the latter, but without endangering the quality of the product. In those regions where wood is abundant, the kiln is often a simple square or circular excavation, about 6 ft. wide by 10 ft. to 11 ft. in height, the interior being lined with dry stones, or, still better, fire-clay bricks. The limestone is thrown in, but not too compactly, so that the flame may circulate, and the smoke escape; the fuel is then placed in a space left in the upper part of the mass. No arrangement whatever is made to concentrate the heat, the loss of which is enormous, and the burning of the limestone is unequal.

The forms employed for better constructed kilns are the right-angled prism, the cylinder, the cylinder surmounted by a truncated cone, the reversed truncated cone, and the ellipsoid ovoide, with variations. The rectangular forms are used in the centre, south and east of France. Bricks and lime are burned in them at the same time. The limestone is placed below, filling up half the kiln, and the upper part is filled with bricks or tiles. When a large quantity of lime is required rapidly, the cylindrical form is employed; their construction is economical and easy, but they do not last long. The limestone is built up like a tower, and covered with beaten earth, the fire being introduced below.

The other kilns are built in a solid and durable manner; no bricks are burnt in them; the large stones are placed below, and the small upon them in the upper cone. The ellipsoidal and ovoidal kilns are for burning by means of coal or coke; their linings are of brick, 16 in. to 20 in. in thickness, set in mortar made of refractory clay and sand.

In the long-flame kilns, fed by wood and heather, the charge rests on one or two arches constructed of the same materials as the kiln; the fire increases with the draught, the mouth is kept filled with fuel, the flame makes its way gradually until the whole mass is in a state of incandescence to the very summit.

VIII. *The Kilns.*—A crowd of circumstances may affect the burning—the quality of the fuel, the direction of the wind, etc. Generally it takes 120 to 150 hours to calcine properly 70 to 80 tons of limestone.

It is almost impossible in long-flame kilns, 20 ft. to 25 ft. high, to burn the paper layers of limestone sufficiently without overburning the lower; in the case of rich lime this is not a matter of much importance, but in that of argillaceous limestone it is fatal, because if overburned it falls into powder and becomes good for nothing. The steam of the water contained in the limestone aids by its expansion in the burning of the upper layers: thus the limeburner prefers the stone just out of the quarry to that which has lost its water.

The burning of argillaceous limestone is also very difficult in kilns heated with coal, the latter being mixed with the stone. The draught is affected in many ways, by changes in the direction or in the force of the wind, by any damage done to the sides of the kiln, by the fact of the pieces of limestone being too unequal in size, and thus not being equally mixed with the coal, and many other accidents which cause the lime to be burnt too much or insufficiently.

IX. MM. Donopp and Deblinne set forth the differences which exist in lime calcined by means of wood, coal, and peat.

1. Lime burned with wood is generally whiter than that produced with other fuel.

2. Lime calcined with peat, slaked and mixed with an equal quantity of water, always precipitates more rapidly than that which has been burned with wood.

3. The calcination with coal produces lime which precipitates very promptly, when, after having been slaked, it is mixed with a certain quantity of water.

Consequently, it is in the interest of builders to employ lime burned with peat or coal, because as its residue does not contain the alkaline principles of lime burnt with wood by the mixture of the ashes, the mortars of which they form part will be of superior quality.

X. Rich lime is obtained from the purest limestone; it is called *chaux grasse*, because when slaked the paste is fine and greasy to the touch. This kind swells and throws out more heat than the others. Reduced to a paste and exposed to the air, it dries by the evaporation of the water which is not in combination with it, absorbs a portion of the carbonic acid contained in the air, and in time acquires considerable hardness; this hardness is much accelerated by the substitution of a current of carbonic acid gas for atmospheric air. In this state, and with the aid of small moulds, tiles and slabs may be made which take a polish when rubbed upon a fine stone, and resemble the finest white marble.

The following analyses of the composition of several materials producing rich lime are by M. Berthier, engineer:

Iceland Spar: — Pure carbonate of lime. The elements are:

Lime	0.564
Carbonic Acid	0.436
	1.000

Carrara White Statuary Marble.— The matter which is insoluble in acid is pure quartz. The elements are:

Lime	0.554
Magnesia	0.001
Clay and quartz	0.010
Carbonic acid	0.435
	1.000

Limestone of Saint Jacques, Jura.— Compact, yellowish in color, forms the basis of the Jura mountains. The elements are:

Lime	0.546
Magnesia	0.009
Clay and quartz	0.015
Carbonic acid	0.430
	1.000

Limestone of the Jurassic formation, forming the superstratum of the iron mine of La Voulte in the Ardéche— compact, yellowish, shelly, density, 2.67. The elements are:

Lime	0.541
Magnesia	0.006
Oxide of iron	0.005
Clay and quartz	0.022
Carbonic acid	0.426
	1.000

Coarse Limestone, tertiary formation in the environs of Paris, very shelly. The elements are:

Lime	0.556
Clay and quartz	0.015
Carbonic acid	0.429
	1.000

Fresh-water Limestone of the environs Nemours, Seine, and Marne—compact, yellow, rather cellular, and very sonorous. The elements are:

Lime	0.548
Magnesia	0.009
Clay and quartz	0.010
Carbonic acid	0.433
	1.000

Fresh-water Limestone of Œnigen, near Constance, Algeria—composed of remains of birds, saurians, and fish, contains a large proportion of organic matter. The elements are:

Lime	0.504
Magnesia	0.018
Clay and quartz	0.069
Carbonic acid	0.409
	1.000

The two following are due to M. Vicat:

Vichy Limestone.—This stone, from the amount of clay which it contains, forms the limit of rich limestones. The elements are:

Lime	48.80
Magnesia	4.76
Oxide of iron, clay, and quartz	2.80
Carbonic acid	43.64
	100.00

The composition of the lime produced from the above stone is as follows:

Lime	86.00
Magnesia	4.76
Oxide of iron, clay, and quartz	5.00
	100.00

The rich lime, which swells most, is evidently the most profitable; but its employment should be restricted to ordinary masonry in elevations; if used for underground or water work, the mortar in which it enters will not harden, but crumble away.

XI. *Chaux Maigre*, or poor lime, so called from the fact that when mixed with water, of which it absorbs but a small proportion, it is short and hard, not sticky and unctuous, like *chaux grasse*—it scarcely effervesces at all. It is produced from limestone containing mineral oxides and magnesian products in considerable proportions. Like the preceding, it is quite unfit for use under water or in damp places.

XII. *Hydraulic Lime.*—When *chaux maigre* possesses the special property of hardening under water, it is called hydraulic lime. M. Vicat subdivides the various kinds under three heads, according to their rapidity of hardening:

1st Class.—*Medium Hydraulic*, containing 82 per cent. of lime and 18 per cent. of clay.

2d Class.—*Hydraulic Lime*, containing 74 per cent. of lime and 26 per cent. of clay.

3d Class.—*Eminently Hydraulic*, composed of 70 per cent. of lime and 30 per cent. of clay.

The first sets after immersion for fifteen to twenty days; the second, in six to eight days; and the third in two to four days. The lime is considered to have set when it will support a knitting-needle, filed square at one end, and loaded with a weight of 10 ounces, without any sensible depression being produced. In this state it will resist the finger with a pressure of 10 to 12 pounds. A fragment of it will not bend, but break.

The hydraulic limes have little color. They have generally a muddy grey, unburnt brick, or yellow tint. Their swelling, as compared with the unctuous limes, is scarcely noticeable. The best and dearest of all the kinds known in France is that of Saint Quentin.

XIII. *Analyses of the Limes.*—The following table contains the results of analyses by MM. Berthier, Rivot, Delesse, and H. Deville, of the best known hydraulic limes, ten being of the class called "hydraulic," and six of the denominated "eminently hydraulic:"

Percentage of the Elements of these Limestones.

	"Hydraulic."	"Eminently Hydraulic."
Carbonate of lime....	51.33 to 89.2 per cent.	52.47 to 82.5 per cent.
" magnesia	In 1 case 40.91; gen. 2 to 3 per cent.	44.25 in 1 case; gen. 1.5 to 4.5 p. c.
Clay.....	5.50 to 15 per cent.	3.25 to 23 per cent.
Gelatinous silex.....	15.3 in 1 specimen only.	None.
Quartz sand and clay	15.0 " "	"
Alumina, with a little oxide of iron.	2.6 " "	"
Oxide of iron.....	Trace " "	"
Carbonate of iron....	0.58 in 1, and 6.2 in another.	3.0 per cent. in 1 case.
" manganese	None.	1.5 " "
Iron pyrites.....	0.80 in 1 specimen.	None.
Soda and potash.....	0.12 "	"
Water.....	1.0 to 4.5 per cent.	"

Percentage of the Elements in the Limes made from the above.

	"Hydraulic."	"Eminently Hydraulic."
Lime.....	53.82 to 78.29 per cent.	53.05 to 70 per cent.
Clay { Silica.....	10.25 to 26.14 "	13.40 to 29 "
Clay { Alumina.....	1.54 to 8.69 "	Traces in 1 instance only.
Quartz sand.....	1.71 in 1 case; 35.93 in another.	" "
Magnesia.....	From a trace to 1.34 per cent.	Trace to 39.71, in 3 cases only.
Oxide of iron.....	Traces.	1 to 4.10 per cent. in 3 "
" manganese..	None.	4 per cent. in 1 "
Sulphate of lime.....	1.15 in 1 case; 1.24 in another.	None.

The best manner of preserving these hydraulic limes, when they come from the kilns, is to strew the bottom of the receptacle, which must be perfectly dry, with slaked and sifted lime, to the depth of about 3 in., and to place about the same quantity, or rather more, of the same over the top of the lime when the receptacle is filled.

When the proportion of clay exceeds 30 per cent. in hydraulic lime, it can only be slaked by means of boiling water. Powdered and mixed, this lime sets immediately. It does not, however, retain its hardness, but falls into powder or paste, according to the state of the atmosphere. This is called *chaux limite*, but it constitutes by comparison the limit between lime, the cements, and the puzzolanos.

NITRO-GLYCERINE EXPLOSIONS.

By CHAS. L. KALMBACH, M. E.

Written for Van Nostrand's Engineering Magazine.

Having manufactured, solely for my own use, nitro-glycerine, fulminate, gun-cotton, and the dynamites, for nearly nine years, and having expended these materials under a great variety of circumstances, on land, in mines, and under water, I have been enabled to accumulate a great number of facts concerning their character. This experience has forced me to dissent from many important and universally received maxims, governing the storage, transportation, and use of nitro-glycerine, and the compounds made of the same. The fact that during all that time I have never met with the slightest so-called accident, confirms my faith in the deductions I have made from these observations.

Incidentally, while engaged in these labors, I discovered some improvements in the economical application, as well as in the compounding, of nitro-glycerine with absorbent materials, which improvements are covered by letters patent. Since, however, the specifications cannot relate my experience nor give the reasons for the system of rules I employ, I am induced to publish these notes to the end that the attention of others may be drawn to a system which has proved so eminently successful in my hands.

On the 14th of April, 1866, an explosion of nitro-glycerine occurred in Wells, Fargo & Co.'s office, San Francisco, resulting in great loss to life and property. A suit for damages arose, which is on record in vol. 15, p. 524, of Wallace's Reports, United States Supreme Court. From the testimony of the experts examined I quote: "Explosion of nitro-glycerine is produced by *percussion* and *concussion*, by a *high degree of pressure, but not by contact with fire.* If flame be applied it will burn slowly, without exploding, and when the flame is withdrawn it will cease to burn. It will also explode when *subjected to a heat of* 360 *degrees Fahrenheit.*"

I believe that the causes of explosion enumerated in the above quotation are to this day universally received as *axioms*, and that the fact of their unquestioned reception is the fruitful source of many accidents. I assert that but one of them is true and worth guarding against, namely: Nitro-glycerine will explode when heated to *about* 360 Fahrenheit. I will also state that all compounds containing nitro-glycerine will explode when heated to that degree. Simple concussion or percussion will not explode nitro-glycerine nor the dynamites.

A bottle or other frangible vessel partially filled with nitro-glycerine may be thrown with great violence, or from a height on rock and shattered without producing explosion. Surely here we have concussion or percussion. But what happens if a tin can or other strong flexible vessel filled with nitro-glycerine is subjected to such an ordeal? Such can will invariably explode when it strikes. The reason is evidently this: Arrested motion converted into heat. The glass bottle breaks by first contact, releasing the contents and allowing them to scatter, thus measurably continuing the motion; The flexible vessel, however, if strong enough, does not release them, but dents or flattens in the direction of the line of motion, thus reducing its cubical internal measure and producing on the contents rapid or rather *percussive compression.* This compression evolves an amount of heat exactly depending on the weight of the canister and the rapidity of its motion. For this reason it is difficult to explode the dynamites by similar force and under identical conditions. Being porous and capable of *yielding* to compression *to a degree*, they are incapable of evolving the necessary amount of heat for such explosion. It is possible, of course, to compact them sufficiently to neutralize that elasticity and evolve the heat necessary—in fact they are so compacted every time they are exploded in a mine, but it is evident that the conditions necessary are difficult to attain in the ordinary circumstances attending their storage, handling, and shipment.

Flame may be applied to nitro-glycerine, and it may thus be burned *on its surface* without explosion, provided: that the burning be interrupted before the unburned mass attains the explosive 360° of heat. The dynamites may be burned safely, because, being porous, they are poor conductors of heat and do not absorb it readily from the burning surface as the pure nitro-glycerine does. But it would be unsafe to burn a considerable amount of them in a thick metallic vessel, as the metal would carry the heat from the upper burning portion to the bottom and thus cause explosion.

The report next mentions "high pressure" as a factor of explosion. It is true that every explosion is attended, or rather *preceded*, by a high pressure, but it is a pressure developed instantaneously and the most *efficient generator* of the heat required. Pressure applied so slowly as to allow the dissipation of the heat generated *cannot produce explosion.* For this reason I doubt whether nitro-glycerine can be exploded in a vacuum.

The report then stated that: "It does not explode by the application of fire," which is true enough, if the fire be applied to the open surface of nitro-

glycerine of *normal temperature*, but that is certainly the only way in which fire may be applied to it without producing an explosion. A glowing coal, a hot iron, or a gas jet, applied to the bottom, or even the side, of a tin can, *will* explode it, for it will heat the film in immediate contact to the explosive point, producing an initial explosion. I say "initial," because if the vessel is entirely open and the point of contact small, the gases produced by the explosion of the film will merely throw the other fluid, nitro-glycerine, aside and escape with a crackling noise. If the can be full, or closed, or if the mass be frozen, or of great *height above the point of contact*, the whole will explode, because it cannot get out of the way of the pressure of the first or initial explosion, and this "initial" produces the required compression for the necessary instantaneous evolution of heat. On the other hand, a pan holding a moderate depth of nitro-glycerine may be set over a slow fire and entirely evaporated without an explosion, because the fire evaporation keeps the temperature below the explosive degree. Dynamite is subject to the same law, and differs only to the extent of its porosity.

Nitro-glycerine, if ever so carefully prepared and washed, will slowly decompose, yielding fumes of nitrous acid. If strictly confined these fumes accumulate and exert pressure, which pressure makes it peculiarly sensitive to percussion. This fact has been (doubtless) the sole cause of many, apparently mysterious, accidents.

I find, then, but a single primary cause for the explosion of nitro-glycerine, viz.: Heat of not less that 360 degrees Fahrenheit.

I also find that the most direct and efficient way to produce such a degree of heat is by percussive compression.

Knowing the primary cause of its explosion, it should be comparatively easy to make, store, transport, and use, nitro-glycerine in such a manner as to avoid all conditions favoring that cause.

It being important to give free access of, or rather to the, air, it should be stored in shallow, open, non-metallic vessels, which should not be filled to a greater depth than their diameter.

Stone, or earthenware, glazed i .side, is the best material for such vessels, because: It is not affected by acids, not a good conductor of heat, and it is strong, stiff, and brittle. Such vessels are cheap and easily obtained everywhere, lasting an indefinite time. The flexible metallic can is supremely dangerous and unfit for the same reasons.

The shallow, open vessel gives another material advantage in the fact that the contents are always fully visible, and any change in appearance indicating dangerous decomposition may be at once observed and provided for, for it always *does* change in appearance long before a dangerous stage is reached.

When during, or rather immediately after, manufacture, the acids containing the nitro-glycerine are washed in an abundance of well agitated water of a *low temperature*, the precipitated, heavy oil has a white, curdy appearance not unlike buttermilk. It is then in its *very safest condition*, as it is impossible to explode it by any ordinary degree of compression. It is, however, just as strong as it ever is under other and more sensitive conditions. I have sent a rifle ball through a tin canister of it without producing explosion, and have fired a strong fulminate primer in another with the same result, viz., tearing the vessel and spilling the contents. When the latter experiment, however, was repeated with a strong champagne bottle the explosion occurred, because the sides of the bottle were strong enough to enable the primer to exert the requisite compression. Such nitro-glycerine, in a temperature of 70° F., will retain this appearance and this quality for one and even two months.

Since it adds so much to the safety it is worth the trouble to store a supply sufficient only for that length of time.

Such nitro-glycerine is peculiarly fitted for shipment and is safest to carry in boxed stone jugs, which are not to be filled quite full, say 3 gallons in a 5-gallon jug. Only a very gradual raising of the temperature will explode such jugs—no amount of crushing force being able to cause explosion, provided the nitro-glycerine remain fluid. As soon as it freezes it separates from the water and will remain so after thawing. Thus it can be made highly sensitive by repeated freezing and thawing. Frozen nitro-

glycerine is dangerous to handle and transport, because it is rigidly confined in its crystals which occupy a less space than the fluid they are formed of. The fracture of a dry crystal will often cause explosion. There is, however, one advantage in keeping nitro-glycerine frozen in store and it is this: When frozen the acidulous decomposition noticed on page 27 cannot possibly take place, but the nitro-glycerine remains perfectly unaltered as long as it remains hard. Since such decomposition is so slow as to be almost imperceptible, and since it is so easily checked and provided for by simple washing and a superposed film of water, I have always avoided freezing because of the risk involved.

I have, in the above, tried to give a full and intelligible exposition of the true cause of the explosion of nitro-glycerine and the means I have successfully applied to avoid unintentional explosion. I only hope that I have avoided all obscurity of expression, as that is the only chance for misapprehension.

CLEVELAND AND THE WORLD'S IRON TRADE.*

From the "London Mining Journal."

DURATION OF SUPPLY.—The Cleveland ironstone has been estimated by Bewick to extend over an area of not less than 420 miles. Allowing a yield of 20,000 tons per acre, it has been calculated that the main seam of the district contains close on 5,000,000,000 tons. Not a few estimates have been made regarding the probable duration of this supply. Mr. Cockburn, manager of the Upleathan Mines, in a paper read before this Institute in the year 1869–70, calculated that first-class stone would be found in the Cleveland hills for 73 years to come, allowing an average weekly consumption of 75,000 tons. It is pretty well known that this consumption has already been surpassed. Including the ironstone vended from the Rosedale Mines of Messrs. Morrison and Leeman, and the Hinderwell Mines of Palmer's Shipbuilding Company, the total average weekly output of ore is now over 100,000 tons, so that, according to Mr. Cockburn's estimate, the period of the exhaustion of our best mineral—assuming a continued ratio of increase—is likely to be arrived at within (say) the next 60 years. Mr. Cockburn's calculation, I believe, leaves the top seam, as well as the upper and lower oolitic, intact, and yet Bewick placed the duration of the same source of supply at 680 years, and allowed 800 or 900 years as the limit of duration over which the inferior seams would be capable of extending. Mr. Jones, secretary of the Cleveland Ironmasters' Association, is reported to have stated in 1872 to the committee on the Cleveland Extension Railway Bill, that the supply of ironstone in the Cleveland district would last for a hundred years at an increasing ratio of consumption, and it was calculated by the same gentleman at that time there were about 300,000,000 tons under lease and worked, being equal to 37 years' consumption at the rate of 7,740,000 tons per annum. It is of little use taking into account the thin and inferior seams, as they are nearly all too coarse and silicious, and contain too small a percentage of iron to defray the cost of working. It is, therefore, on the main seam that the prospects and prosperity of Cleveland must depend. It would probably be found that with a more exact definition of the area of the ironstone field embraced within their calculations the fignres given by Messrs. Bewick and Cockburn would more nearly coincide than they now appear to do; but whichever estimate we accept, the period of the exhaustion of our supplies of ironstone is placed at so remote a date that it need not further enter into our calculations. It has hitherto been, and still is, the custom to speak of the ironstone of Cleveland as practically inexhaustible, and this we may here confidently assume to be the fact.

* From a paper read by Mr. J. S. Jeans before the Society of Cleveland Engineers.

Compared with other Iron Fields, the ironstone can be worked at a cheap cost. Until within the last three years its price did not generally exceed 3s. 6d. per ton, and it could be mined for 10d. per ton. There is scarcely any other district in which more economical results are obtained. In Lincolnshire, it is true, the ore is quarried at a cost of 6d. to 8d. per ton, and is sold at the mine for 2s. 6d. to 3s., but then the ironmakers of Cleveland will not hesitate to affirm that the Lincolnshire ore is not so uniformly well adapted for smelting purposes as the ore of Cleveland; and when it was found necessary last year to make use of it in lieu of the native stone, it involved no end of trouble in the working. Scotland has what seems at first sight a superior advantage to Cleveland in the closer juxtaposition of its minerals, the splint coal being found not unfrequently in the same measures that yield the iron ore; but both the splint or smelting coal and the blackband ironstone of Scotland are near exhaustion, and retrogression has consequently marked the course of the Scotch iron trade during the last two years. Staffordshire and Wales have such inadequate supplies of local ore that they are compelled to import the great bulk of what they consume from foreign sources. Northampton has of late been brought into considerable prominence as a source of supply, but the position of the district is even worse than that of either of the three older districts here enumerated, seeing that it labors under the insuperable want of a proximate source of coal supply. It is scarcely necessary to extend our comparison into North Lancashire and Cumberland, for in addition to the great cost and uncertainty attached to the mining of iron ore in these districts, the former with an ample supply of hematite is compelled to bring the great bulk of its fuel from South Durham, at a freightage rate of 8s. to 9s. per ton, while the latter, with a proximate supply of inferior coal, is chiefly dependent on the Cleator Moor district—a restricted and rather precarious source of supply—for its ironstone. Unaided and alone, the ironstone of Cleveland would never have placed that district in the proud industrial position it now occupies. The contiguity of the South Durham coal field, with boundless supply of the finest fuel yet found to be available for iron smelting purposes, has been the ladder on which Cleveland has mounted to exceptional prosperity. The Durham coal field is within 1s. 6d. or 2s. per ton of Middlesborough, and the development of the Durham coal trade has followed that of the iron trade of Cleveland in an unvarying ratio of increase.

Iron Manufacture on the Continent.—Spain has large tracts of iron ore in the district around Bilboa, now being largely developed by English capital, but there is no sufficiently contiguous coal field to favor the erection of iron-works on the spot. Besides the coal of Spain is very inferior in quality, containing a low proportion of carbon, ranging from 45.5 to 82.0 per cent. Russia also has to combat the difficulties of a limited and inferior coal supply, the total area of its coal field being not more than 100 square miles, while the coal often contains as much as 17.1 per cent. of ash to 38.7 per cent. of carbon. A good deal has recently been done to develop the mineral resources of Russia, for we find in a recently published return it is stated that there were 1174 iron mines in operation, and that the production of pig-iron was at the rate of 354,000 tons per annum; but, notwithstanding that there are numerous rich deposits of iron ore, the scarcity and inferiority of the supplies of fuel must always operate to the detriment of its metallurgical industry. Commencing in Luxemberg and terminating in France, there is a field of ironstone 150 miles in extent, which corresponds in geological position with our own. The ore varies from 6½ to 16½ feet in thickness, and yields about 32 per cent. of iron. The same field may be followed into Alsace-Lorraine, where it attains a uniform thickness of 13 feet, and where the mines are close to the furnaces. Mr. I. L. Bell has found that iron can be made here more cheaply than on the banks of the Tees, but the fuel available for smelting purposes in this part of the Continent is so deficient alike in quantity and quality that, in spite of cheaper labor and other collateral advantages, there is not much scope for any great development of production unless, indeed, there shall meanwhile be found greater

capabilities of fuel supply than are now known to exist. There is no other European country that threatens to come within sight of England in the manufacture of iron, if we except Belgium, which has long been held up as the *bête noir* of the British industrial, and of whose rivalry we are still hearing reports from day to day. No one who knows anything about the relative industrial conditions of the two countries will seriously admit that any ultimate danger is threatened to England from Belgian competition. Here and there a Belgian firm has wrested an order from the English iron trade; and the opposition thus confronting us has been more seriously felt since the tide of industrial prosperity commenced to ebb, some 15 or 18 months ago. But there can be no permanency in the hold which the Belgians have been able to seize upon the markets of Europe. So far as its natural resources are concerned, Belgium is one of the most impoverished nations in Europe. Its coal field does not cover an area of more than 510 square miles, as compared with 5,400 square miles of coal area in Great Britain. Its collieries are generally worked under very great difficulties, and its ironstone is all but exhausted. Out of 700,000 tons of iron ore required to produce the 610,000 tons of pig-iron made in Belgium in 1871, not more than 100,000 tons were raised in Belgium itself, the residue being almost entirely from the Grand Duchy of Luxembourg, so that the bulk of the ore has to be carried a distance of over 100 miles, while much of the ore does not contain more than 26 to 27 per cent. of iron. But, in addition to these drawbacks, neither the ironstone nor the fuel supplies of Belgium are equal in quality to those of England. The fact is that the Belgians hold their high position among industrial nations not because but in spite of the natural resources of their country. Cheap labor, an avoidance of all avoidable waste, contentment with small profits, and patient industry have really and solely made Belgium what it is; and I hope that I shall not be considered presumptuous if I venture to add my opinion that it has reached its utmost limit of development so far as the iron trade is concerned. Already it imports from England a great deal of the pig-iron and fuel required for its manufactures, and so long as it is handicapped to this extent it is manifest that "if England to herself do prove but true," nothing that Belgium can do need furnish cause for alarm or apprehension.

American Competition.—And now I approach what is to me the most interesting, and to others will appear the most important, part of my subject—the consideration of the rivalry that the iron trade of England is henceforth to experience from America, and probable extent to which American ironmakers will in the future supplement or supersede the iron production of this country. Hitherto, it must be admitted, the iron trade of America has not made the progress that was reasonably to be expected, nothwithstanding that it has been unnaturally stimulated by a protective tariff of import duties. There are five iron-making regions in the United States, of various extent and importance. Chief among these is the region of Lake Superior, the great tract of country lying west of the Alleghanies. It extends by Lakes Superior, Huron, and Erie towards New York State, and by Lake Michigan into Wisconsin, Illinois, and Indiana, and abounds in ores yielding from 50 to 60 and even 70 per cent. of iron. In the Michigan iron range there is an immense deposit of the best black magnetic ore, which yields from 65 to 69 per cent. of iron. For the most part these deposits lie within easy reach, and mining is never deep and difficult as in this country. Often it is mere quarrying, and the "bluffs" which contain the ores frequently allow of tunneling, with a slope under the ground. All through the States, indeed, there is an abundance of iron ore of a quality rarely found in this country, and in the Lake Superior region alone 1,197,000 tons of iron ore were raised in 1873, valued at the mines at over $8,000,000. The fuel of America is generally well adapted for smelting purposes, and distinguished for a high degree of purity. It is not, however, so much in the superior quality of its resources as in their magnitude that America will probably overtake and ultimately surpass Great Britain. The coal fields of the United States are estimated by Prof. Rogers to cover an area of 196,650 square miles, while a further coal area of

7,530 square miles is contained in the British Provinces of North America, making together a total coal area of 200,000 square miles, as against 5,400 square miles of coal area in Great Britain. These figures simply represent the difference between an easily exhaustible and a practically inexhaustible supply, for although much of the coal of the United States may not be within reach of working, there will be millions upon millions of tons left unworked when the last ounce of available coal has been extracted from the coal fields of Great Britain; and if ever England is reduced to the necessity of importing her fuel from America or China, "the day of her manufacturing prosperity—to say nothing of her supremacy—will have gone for ever." At the present moment the production of pig-iron in America is a little over a third of the total production of Great Britain.

The total number of blast furnaces available for use in the United States, according to the most recent statistics, is 575, and of that number 348 only were in blast. It is rather remarkable that, notwithstanding the abundant coal resources of the country, more than 200 of these furnaces burn nothing but charcoal; of the remainder 181 burn coke, and 187 burn anthracite. One of the greatest difficulties in the way of the development of the American iron trade is the general absence of a proximate coal field to the ironstone measures. In some cases the coal has to be brought a distance of many hundred miles to be smelted on the spot where the ironstone is found; and in other cases the iron stone is brought a long distance to the coal. The drawback incidental to the geographical association of coal and iron ore is, to a large extent, discounted by the splendid facilities of transport that exist throughout nearly the whole of the United States. Minerals can be carried at a cheap rate along the Ohio, the Delaware, Lake Michigan, the Mississippi, and other inland seas, to the advantages of which, in this country, we are complete strangers. It is undoubtedly true that labor is at the present time cheaper in this country than in America, but labor is an item of cost that can be adapted to circumstances, whereas natural resources are not. There is a want of definite information respecting the fuel supplies of America; and in the last report of Her Majesty's Secretaries of Embassy and Legation a doubt is expressed as to whether the coal resources of America are equal to keeping pace with her requirements in iron smelting. But every accession to our knowledge on this matter only tends to strengthen the conviction that the fuel of America is not only practically illimitable, but in the main admirably adapted for smelting purposes. Americans have also of late years essayed to excel the manufacturers of Cleveland in their greatest achievements. The "Cambria" furnace at Johnstown, with a capacity of 15,020 cubic feet, and the "Lucy" furnace at Pittsburg, yielding 475 tons of Bessemer pig-iron per week, have become quite historical; but these furnaces have recently been left in the shade by one built on the banks of the Alleghany, which sometimes produces as much as 101 tons of pig-iron in a day, and can yield with unvarying regularity from 650 to 660 tons of foundry iron in a week. We have never heard of a blast furnace in Cleveland that yielded anything like this result, despite the fact that we have long boasted of having the biggest and most productive furnaces in the world. Habitual optimists on the one hand, and rest-and-be-thankful economists on the other, have been diligently trying to explode the notion that America will one day become a competitor with England, not only in United States markets, but in all other markets in the world. They say that America has not the capital necessary to enable her to overtake and rival England, forgetting that the accumulation of capital is only a work of time. They say also that the purchasing power of money is so much less in the United States than in Europe, that the manufacturers of the former could never successfully compete in the markets of the latter; but it is easy to perceive that closer assimilation in this essential is not only attainable, but certain, sooner or later, to be attained through the exigencies of commercial intercourse. It was, moreover, believed not long ago that, owing to some defect in the clay of which American blast-furnaces were built, the cost of providing plant and keeping it in repair would seriously handicap Amer-

ican manufacturers; but we now learn that the "Mount Savage" brick of the States excels the Scotch or German, or even the famous Stourbridge, so that unless the rich ores of America prove too much for any clay, the building of monster blasts will probably become the rule of the future. Taken as a whole, therefore, it may fearlessly be maintained that America lacks none of the essential elements of manufacturing greatness, while her ultimate resources surpass those known in Europe by as much as a mountain surpasses a mole-hill.

General Conclusions.—Cleveland is now the only known iron-producing district in Europe likely in the future to come into active competition with America, and that if the resources of America were less than they are, the development of the Cleveland iron trade would probably proceed at a much more rapid pace. Hitherto the American iron trade has been defensive rather than aggressive in its tendencies. It has been content with seeking to supply home requirements. But this endeavor it has realized with a success at once startling and inimical to the manufacturers of Europe. Within the last three years the United States have fully doubled their resources for the production of pig-iron, and they have increased their production of malleable iron from 1,500,000 in 1871 to 2,000,000 tons in 1873. It is not necessary to weary you with figures showing you how the exports of all kinds of iron from this country to America have fallen off within recent years, or how that falling off has affected Cleveland in particular. It is abundantly evident that America has learned to depend upon herself, and year by year we will continue to lose our hold upon American markets until we are shut out altogether. But while America will become her own ironmaster, she is not likely for many years to seek for custom outside her own territories. She may produce iron more cheaply than it can be imported from England with a high protective tariff in her favor; but she will not be able to undersell the British manufacturer in the markets of Europe. This, then, is the field in which the Cleveland ironmasters must labor in the future; and we think we have already shown that his resources are such as to enable him to cultivate this field more successfully than any visible competitor. In this field the sun of his prosperity will only set when the fuel available for smelting the ironstone of this district becomes exhausted. That, however, must be regarded as a very remote event, notwithstanding the calculations of Mr. Jevons and other statisticians; and if there is any truth in the commonly accepted estimate that there is just about sufficient fuel left in the Durham coal-field to smelt the ironstone contained in the main bed of Cleveland, our capitalists may rest in undisturbed security, for no one will wake up in their generation to find that exhaustion has at length overtaken us.

THE SEWAGE OF PARIS.

From "The Engineer."

In certain respects Paris is in a worse position for the satisfactory disposal of her sewage than London. It is true that her population is much smaller, and the area of collecting ground more manageable; but, on the other hand, the great distance of Paris from the sea renders it impossible to use the latter as a recipient of the sewage sent down from the former. Thus the cost of constructing anything like the terminal canals of our own metropolitan main drainage system would be so enormous that the idea could not be entertained for a moment. In one word, Paris sewage cannot be sent to sea in special channels. For years it was poured into the Seine almost without protest, but the extension of the city, and the consequent augmentation in the volume of sewage to be disposed of, at last became so great that the condition of the river could no longer be tolerated. The construction of a fine system of main sewers, tolerable perfect in every respect except that they lacked a satisfactory outfall, supplied,

no doubt, an additional stimulus to exertion. It became possible at least to collect the sewage of Paris, a thing which was impossible while thousands of subsidiary sewers debouched into the river. Then came a period during which experiments were carried out with various processes for the purification of sewage, all with more or less unsatisfactory results. A farm was established, however, on which a considerable quantity of sewage was distributed with fair promise of success, and at last a commission was appointed on the 27th of August, 1874, to investigate and report on the condition of the Seine, and suggest means for insuring its purification. The commission have just published their report, which we have much satisfaction in stating confirms the views which we have all along expressed. They find that the only satisfactory mode of disposing of the sewage of Paris is to run it on to land; in other words, the system to be adopted is a combination of irrigation and Mr. Bailey Denton's method of downward filtration. The extent of land is to be much larger than Mr. Denton would probably deem necessary; but it is certainly smaller than we think would suffice if the soil were not of great depth, and so porous that the sewage would be fairly purified even if no crops were grown. Having premised this much, we shall now proceed to consider the report more in detail.

The commissioners commence by describing the existing state of the river. The Seine is joined before entering Paris by the Marne, the Yonne, and several smaller streams, all exposed to certain chances of pollution. Yet the condition of the water is stated to be, on the whole, good. Fish flourish in the stream, which runs over a bed of white sand visible through the clear water. Pollution commences as soon as the stream fairly enters the city, but it is limited in character and of small importance until the bridge at Asniéres has been reached. The great main sewer running north through Paris discharges itself close by at Clichy, and the contents of this conduit appear to be incredibly nasty. The report goes a good deal into detail about dead dogs and cats, and scum, and organic refuse. The picture drawn leaves, indeed, little if anything to the imagination, and nothing to be desired. In moderate weather the Stygian flood keeps the middle of the stream, but in heavy rains the force of the current in the river is too much for that issuing from the sewer, and the sewage is compelled to run close to the left bank. On this bank a filthy deposit is left as the river falls. Of this we shall say nothing in the way of description. It will suffice to state that nothing that we have ever read or heard of can, apparently, be more insufferably disgusting. The pollution extends a long way down the stream—how far we do not know with precision. Oxidation and deposition do their work by degrees, and the nuisance is abated after miles have been traversed. But the Seine, we need hardly say, is never really pure—we use the word in the mildest sense—after it has passed through the bridge at Asniéres. Such being the position of affairs, the commission had to consider how best to improve matters. Five distinct schemes for effecting this object appear to have been carefully weighed. The first was the extension of the main sewers to the sea—which was at once set aside because of the expense. The second contemplated the extension of the sewers to the confluence of the Oise. But this would only carry the nuisance to the banks of the Oise and was accordingly rejected. The third scheme was essentially novel. The sewage was to be diluted by the addition of pure water near the outfalls, and still suffered, as before, to escape into the Seine. We need hardly say that this ingenious proposition was rejected. Fourthly, it was proposed that the sewage should be passed through large filtering beds, and the clear water delivered into the Seine. This scheme was rejected because, as the commissioners point out, filters require incessant attention, and, after all, they only remove solid impurities. The fifth scheme was to construct immense settling tanks near the outfalls, to collect the dead dogs and other solid matters. This would obviously only eliminate a portion of the evil, while the settling tanks, which would need to be very large, would prove a dangerous nuisance in hot weather, and this idea was accordingly abandoned. Nothing remained but irrigation, downward filtra-

tion on Denton's system, or purification by some of the numerous patented schemes before the world. That which appeared most likely to succeed was the precipitation system. To test its value, a series of experiments were carried out at the suggestion of M. Chatcher, Inspector-General of Mines. Reservoirs were established at Clichy on a great scale, and on the 11th of October the commissioners saw as much as 600,000 tons of sewage treated by the sulphate of alumina process. The result was, that the water was discharged clear, but not pure. Careful experiments made in 1868, showing that two-thirds of the nitrogen and one-third of the volatile or combustible materials of the sewage were left in the water, which was unfit for any, even the commonest domestic uses, and could not possibly be discharged into a river without contaminating it. What was true in 1868 is, of course, equally true of the process in 1875. The report deals very fairly with this question, and shows honestly and dispassionately why it is that all these sewage processes must fail, except as palliative measures. It is estimated that Paris discharges annually about 260,000 cubic yards of solid matter suspended in the sewage. Now, a depositing process would have to provide for the disposal of this huge mass of mud. How can this possibly be effected? If by artificial heat, the cost would be enormous. If by natural means, the space occupied by the filthy mass would be very great—not much less than 150 acres. A nuisance would be unavoidable; and the process of desiccation could scarcely be carried on at all in winter. But when the mud had been so far dried that it could be carted or otherwise manipulated, what would become of it? The theory of the believers in "processes" is, that it would constitute a very valuable manure, worth as much as 50s. a ton, or more. The report before us explodes this fallacy. In France, at all events, dry sewage mud is only worth from 6f. to 10f. a ton, which is just about the cost of the chemicals used. The expense of pumping, drying the mud, and otherwise manipulating the sewage, remains undefrayed, even if a ready sale could be had for the mud. So that the cost of carrying out the process would be very heavy, even if the value of the residuum were maintained, which is, we may add, to the least degree unlikely, as it would not pay to transport so worthless a material to any distance by road or rail, and the landowners in the vicinity of the purification works would soon find that they could dictate their own terms, because the authorities would be compelled to sell the product at any price, and rest content so long as they get rid of it. The commissioners estimate that the adoption of the sulphate of alumina process would cost the ratepayers of Paris and its environs £40,000 a year, and very wisely rejected it without further scruple, as being at once unsatisfactory as regarded the effluent, unmanageable on a large scale, and expensive.

After a review of the various schemes we have cited, the commissioners go on to state that the solution of the question must be sought not in chemical processes of purification, but in the combined action of the soils and plants on sewage. They are very careful, however, to qualify this statement by adding that the soil must be permeable. They thus evidently clearly appreciate the conditions under which sewage can best be applied to irrigation purposes. Experiments were carried out by the commission to test the advantages of downward filtration; and Mr. Denton will rejoice to learn that the results obtained were eminently satisfactory. A glass vessel half a metre high, filled with earth and sand from the plain of Gennevilliers, clarified for a long period sewage discharged on the surface. The commission analyzed the sewage with which they had to deal, and the variety of plants which they proposed to cultivate, and they have arrived at the conclusion that for each crop 7,800 cubic yards of sewage, or, say, 1,306,000 gallons, should be applied per acre. On this point the commissioners are probably wrong in principle, as the quantity appears to be excessive, but they are apparently right, taking into consideration the nature of the soil with which they have to deal, in assuming that each acre of irrigated land will purify about 24,000 cubic yards of sewage per annum. We shall not attempt to reproduce here a description of the existing works at Gennevilliers, where the irrigation system has for two years been at work; it

must suffice to say that about fourteen miles of ditches distribute sewage, raised at Clichy by centrifugal pumps, over a farm of about 353 acres. The commissioners carefully examined the farm, and investigated all the particulars connected with it, and they finally arrive at the conclusion that the only remedy for the pollution of the Seine is the direct application of the sewer water to agricultural purposes, and that a permeable soil, like that at Gennevilliers, is favorable to the cultivation of market garden produce, plants for manufacturing purposes, and grass, and that no injury to the health of those living near the sewage farm is to be feared. We cannot, for lack of space, enter into a detailed consideration at this moment of the arrangements proposed by the commissioners for carrying out their scheme. The works existing at Gennevilliers were constructed with a grant of £40,000, made for the purpose in 1872. In 1874 a similar sum was voted for extension of the works, and, when these are constructed, about 2,470 acres will be available for irrigation, and these will dispose of about fifty millions of tons of sewage per annum, or half the total volume of water now collected by the sewers of Paris. As regards the other half, it appears that west of the present farm more land can be obtained at Gennevilliers, to the extent of nearly 3,000 acres, and it is estimated that all this might be brought into use by an outlay of £200,000. This would dispose of the whole of the sewage of Paris. Land might also be obtained near St. Germain, and the commissioners think that it would be well that this should be examined before taking another tract at Gennevilliers.

We have done little more, it will be seen, than give the heads of one of the most interesting documents yet contributed to the literature of sewage; we shall return to the subect. Meanwhile, we would express the hope that the publication of this report may do something to place matters on a more satisfactory footing in this country. If it is once proved that there is no way of disposing satisfactorily of sewage but by turning it on land, we may hope that the Legislature will interfere to such an extent as will simplify the present process of obtaining sewage farms. The energies of corporations are too often wasted now on various schemes more or less conflicting, and it is too commonly argued that it is much better to try a process than incur the cost of purchasing a sewage farm. While an alternative remains for adoption, time and money are certain to be wasted by local boards. The report of the Paris Commission has done much to prove that irrigation without alternative must, in the long run, be adopted, and we trust the conclusion will be accepted as nearly, if not absolutely, final.

NOTES OF A VISIT TO MINES AND IRONWORKS IN THE UNITED STATES.*

By I. LOWTHIAN BELL, F. R. S.

From "Iron."

Mr. Bell began by saying that in the year 1871, one-half of the iron produced in England was exported to foreign countries, and one-fourth of this half was despatched to the United States, in all about 750,000 tons. In the year 1874, however, the States only took 130,000 tons, and it was stated that during the three years the producing power of that country had risen from two and a half millions to four millions of tons. It is a matter of great interest to the British ironmasters to learn whether this extraordinary growth is due to the stimulus of our own excited markets, and whether the increase can be actively employed when iron falls in value to what experience has accustomed the world to pay for this commodity. In touching upon the question of transport, which so nearly relates to the manufacture of iron, he said that the raw material in America has to be carried over distances quite unknown in this country. This applies

* Read before the Iron and Steel Institute.

also to the manufactured product. A great deal is done by water, and, as an instance, he gave the cost of conveyance of coal from Pittsburg down the Ohio. Twenty thousand tons of this mineral are sometimes embarked on board a flotilla of flat-bottomed boats, and conducted by one steamer, for a distance of 1,600 miles at something under 1s. per ton, which includes the cost of bringing back the empty barges. The entire question of internal intercommunication of the United States has experienced great changes in consequence of the enormous development of the railway system. The Hudson River, which is accessible by the Great Eastern Railway for seventy-five miles above New York, has a double line of rails running alongside its stream beyond the city of Albany. Thus the locomotive has not only, in many cases, displaced the marine engine, but it has brought mineral districts into communi cation with each other, which, without it, would in a great measure have remained useless. A limited quantity of charcoal iron can be, and is, produced from the rich ores of Lake Superior, the Iron Mountain of Missouri, and Lebanon in Pennsylvania; but the quantity would have remained insignificant had the rail not enabled these minerals to be conveyed to the coal of the Shenango and Mahoning Valleys, and to those of the Lehigh, Delaware, Ohio, and others. The railway system has grown into dimensions far exceeding those in England, the land of its birth. At the end of 1873 the United States had 76,651 miles of road, against only 16,082 miles in England. The average cost per mile in the latter has been £36,582, and in America not one-third of that sum. In the latter case, however, the Americans have had the advantage of getting their land for a mere trifle, but they have had to contend with scarce and dear capital, and with materials and labor far more costly than in England. They have not constructed such substantial lines, however —the convenience of the many being allowed to override the possible injury to the interest of the few. The working charges in the States absorb 65.1 per cent. of the gross earnings, and in this country only 53 per cent. The rates of carriage also vary, some charging 1½d. per ton per mile, and others only ½d.

Looking at the fuel consumed in the manufacture of iron in America Mr. Bell first referred to charcoal, and remarked upon the large quantity of forest land to be found. In the earlier history of the iron trade it was almost exclusively used in the blast-furnace, and even in 1854 one-third of the pig-iron produced in the United States was smelted in the charcoal furnace, or about 300,000 tons; now it is 500,000 tons, or one-fifth of the entire make. It is mostly used for railway carriage wheels. The prices of charcoal vary according to the district, and Mr. Bell gave instances. He spoke of the system of weights and measures employed in the American ironworks, and said that this is one of the few things which the people there had done badly. Not content with introducing our unmeaning ton of 20 cwt. of 112 lbs., they have two distinct tons, one of 2,000 lb., and the other of 2,440 lb. Mr. Bell calculates that 46,000 acres of timber fall annually to provide fuel for the charcoal furnace. Less than 200 acres of a four-feet seam of coal, in the county of Durham, would produce the same weight of coke as is obtained from 46,000 acres of American forest. Coal is more abundant in the United States than in any other part of the world, and all kinds are found. In some places natural gas is used for puddling, reheating, &c. Of pit-coal itself there are 192,000 square miles, as compared with 8,000 square miles in the United Kingdom; and Mr. Bell thinks it may be doubted whether there is any similar area in the world in which a larger proportion of the surface is occupied by coal-bearing strata. The anthracite fuel is much used in the blast-furnace, indeed, out of two and a half millions of tons of pig-iron smelted last year, about one-half was the product of furnaces burning anthracite. From the position which these beds of anthracite coal occupy, it would appear as if, after their original formation, an enormous amount of lateral compression had been experienced by the districts in which they lie. This force has raised the strata into a succession of waves, as it were, the slopes of which vary from an angle of 20 to 45 degs., and occasionally descending to a depth of 200 to 250 fathoms or more. In some cases, this compressive power

has been so great as to have forced one ridge back over its neighbor, to such an extent as to convert what is the floor of the seam of one place into the roof at another, and, from a similar cause, the quantity of coal which has accumulated at the anticlinal axes of some of these coal undulations is so great as to afford a face of 40 to 60 feet, or even more, in thickness. In some cases denudation has carried off not only the sandstones and shales, but a portion of the coal itself, the bared edge of the seam is found immediately under the alluvial matter of the surface. The coal is sometimes quarried; indeed, at Mauch Chunk, there is an open quarry of coals 10 acres in extent, the face of the seam having a height of 70 feet. Peculiar appliances are necessary for extracting this coal, and Mr. Bell described them briefly. The largest blocks known as "lump" coal are chiefly consumed in the blast-furnaces, the others go for various purposes. The "stove" coal is that used for domestic fires, and commands the highest price. Anthracite coal is regarded as a natural coke, as it often contains as much as 93 per cent. of solid carbon. The height of the seams and the nature of the "thrust" by working out the support of a roof lying at a high angle, is the cause of great loss in "pillars," 25 per cent. of the whole contents of the seam being the average. The American coal master has also to contend with a considerable quantity of small, which is entirely valueless, and many acres of land, near the older pits, are covered with it. Sometimes as much as one-half of the whole produce of the mine is thus rejected, but the average is about 20 per cent. of the coal actually drawn. The men engaged in the anthracite mines work from eight to ten hours per day, and are paid on a sliding scale, according to the selling price of coal. Describing bituminous coal, Mr. Bell stated that this is worked without producing much small, and is largely used in a raw state in the blast-furnaces in the Mahoning and Shenango Valleys. In the eastern coal-fields, near Pittsburg, a celebrated coking coal is raised. Near Connellsville the seam is 10 or 11 feet thick, and the coal lies so soft in the ground that a man without the use of powder can shovel a ton an hour into the trams. The entire produce of the mines is converted into coke, and this is considered the best of any in the United States. Mr. Bell, however, thinks that it is greatly inferior to Durham coke. The cheapest coal he heard of is obtained for supplying one of the large ironworks, and, exclusive of royalty, it is delivered at the furnaces for about 3s. per ton. After describing the coal in the various fields, he went on to consider another item of iron manufacture, viz., the supply of flux for blast-furnaces. He stated that there is a vast extent of carboniferous or mountain limestone in America, frequently very near the pig-iron works. Near Baltimore the shells of oysters, which are found in great abundance at Chesapeake Bay, are used. They contain 95 per cent. of carbonate of lime, and are a very inexpensive substitute for lime itself. The United States contains abundant quantities of iron ore of all kinds except the spathose ore, which is very scarce even in Europe. The ironstone of the liassic and oolitic seams, which furnish about one-third of the pig-iron made in the United Kingdom, seems to be entirely wanting in the States. The speaker described first the magnetic iron ore of Lake Champlain, its peculiarities, mode of deposition, &c. Relative to the specular ore of Lake Superior, which is valuable from the cheapness of its extraction, its abundance, and its freedom from deleterious ingredients, he remarked that the contents of the mines are chiefly obtained by open quarry work. The ore yields something like 67 per cent. in the blast-furnace, and is pure enough for the manufacture of Bessemer iron. Mr. Bell next noticed the Iron Mountain deposit. It is of easy reduction; indeed, a furnace only 40 feet high, with boshes of 9½ feet, blown with cold air, will make 100 or 120 tons per week of grey iron, with less than 24 cwt. of charcoal; with moderately hot air 150 tons per week can be run with 20 cwt. of fuel. The yield of the ore may be taken at 65 per cent. The author then described in detail, various deposits of limonite, or brown hæmatite, which he saw, and afterwards touched upon those of red hæmatite; clay and blackband ores also came in for a share of attention. Mr. Bell, in treating of the blast-furnaces, referred first to the establishments which

have been founded for promoting scientific training and education, and he spoke very highly of the earnestness and devotion which characterizes those engaged in the mining and metallurgical industries of the States. He criticised the various matters in which he thinks an improvement might be made, and recommended those worthy of adoption in this country. He stated that the Lehigh makers are a little behind the age in the question of fuel. In furnaces 55 feet high, with boshes of from 17 feet to 18 feet, the anthracite used in smelting an ore yielding 50 per cent. with 12 cwt. of ironstone was about 35 cwt. Perhaps this was due to a want of sufficient temperature of the blast, and so the insufficient height of the furnace. Where ironmasters had been bold enough to erect furnaces of 72 feet high, their experience has proved eminently successful, for the fuel consumed has been reduced to 25 cwt. per ton of iron. In the matter of wages, skilled men are paid at rates below their brethren in England. The furnace-keepers in 1874 received 8s. 6d., against 10s. and 12s. paid last year in the North of England. As a rule, in the States, they have more men employed to do the same work, and this, added to some superiority in arrangements, enables English makers to smelt a ton of iron for considerably less than the amount paid in wages in Pennsylvania. Mr. Bell spoke highly of their blowing machinery. He stated that the make of the 55 feet and 60 feet furnaces of grey iron may be taken at 200 tons, and that of the larger at 300 tons per week. Remarking on the very large make of some of the Pittsburg blast-furnaces, Mr. Bell stated that their whole secret lies in forcing the air into the furnace at a high pressure, 8 lb. to 9 lb., and in immense volume. The ready reducibility of the ores is also favorable to a large make. Going on to the malleable ironworks, Mr Bell remarked that the quantity of pig-iron puddled is less than in this country, as a large quantity of old rails are annually worked up in the mills. The greatest number of puddling furnaces in any one establishment is at the Cambria Works, at Johnstown, Pennsylvania, but they cannot turn out above 600 tons of puddled iron per week, although their make is equal in steel and iron rails to 100,000 tons a year. In the States there are 899 double and 2,063 single puddling furnaces, which together only produce about 2,000,000 tons of puddled iron, or 1,750,000 tons of finished iron. The prices for puddling vary considerably in different localities. In Troy, the rate is as low as 19s. per ton, in the Lehigh Valley 21s. 9d. is paid, and at St. Louis and Chattanooga 24s. 6d. At Pittsburg 22s. 7½d. was paid at the time of Mr. Bell's visit. He could not give a very satisfactory account of the progress of mechanical puddling in America. He referred at length to the Danks' progress, and stated that during his visit to Messrs. Graff, Bennet & Co.'s, where they are in operation, the work was going on in a satisfactory way, but the furnaces were not used at nights. Mr. Bell believes that rotatory puddling will ultimately be achieved, and it may be the result of some modification of the apparatus invented by Mr. Danks. Whenever hand puddling is superseded by mechanical means, Mr. Danks will deserve great credit for the assistance he has already rendered, not only in perfecting the furnace itself, but in devising other appliances required in manipulating large masses of iron. Mr. Bell noticed the three-high rolls in finishing mills, which are in the United States very generally adopted. The next subject for remark is that of the manufacture of steel. The make last year of Bessemer steel reached 175,000 tons, of which 135,000 tons were used for Bessemer rails. At the Bethlehem Iron Works Mr. Bell saw hot ingots of steel weighing a ton each, taken direct to Siemens' furnace, out of which they were charged and drawn by means of hydraulic cranes. When at a suitable temperature, the ingots were brought to the cogging-mill, which was provided on each side with feeding tables, the invention of Mr. Fritz. These tables consist of two strong frames, the breadth of the rolls, and long enough to support the ingot when rolled out. The frame is furnished with a series of rollers, and supported on the standards themselves is also a roller, the latter forming thus a continuation of the platform of rollers placed on the frames. A man at a small double-cylinder engine is able to set the whole of the rollers on the two feeding-tables, as well as those carried on

the standards, in motion, which he changes at will, by simply reversing his engine. As soon as the ingot is partially on the table the rollers are started, and the ingot is propelled towards, and drawn through the rolls, when it is received on the table behind the rolls. The moment this is done, a second man, by means of hydraulic machinery, raises the two tables to the level of the grooves formed by the middle and top roll. While this is being done, powerful screws reduce the aperture in the rolls, and the ingot, by reversing the rollers, is passed to the front, when the feeding-tables are lowered again to their original position. Underneath the front feeding-table is a traversing frame, to which movement, by hydraulic pressure, can be communicated parallel to the rolls, and at right angles with the rollers of the table. Attached to this traversing frame is a row of five strong bars coming through between the rollers, and bent at the top ends at right angles. By the use of hydraulic power, these bars can be raised and lowered, so that, by means of the traversing frame, they are made to travel at will between the rollers, and pass up through them. The moment the ingot is lowered on the front feeding-table, the bent ends of the bars catch it on the left-hand edge—looking towards the rolls—and turn it over, the traversing frame moves to the right, and the five bars, now projecting above the feeding-table, push the ingot opposite the second groove. The rollers are set in motion, and the ingot is passed through the rolls as before, and this is repeated for each groove in the rolls. In this way the ingots are reduced to the size fit for the finishing mill, without a man ever touching them. After being cut in suitable lengths, they are charged while hot into a second Siemens' furnace, and heated for the rail mill also, with three high rolls, and a masterpiece of rolling machinery for strength and accuracy. Mr. Bell thinks that all that can be said of the blast-furnace process, and the malleable ironworks of America, is that they are keeping fairly up with the British, but, in the Bessemer works, we must look to the United States for superiority of arrangement and some improvement in machinery over our own. He considers the Americans, like ourselves, have done nothing in imitating the French by running the iron from the blast-furnace direct into the converter. Little or no steel was being made in America by the Siemens-Martin steel process. An establishment had been erected on the banks of the Monongahela River, near Pittsburg, for carrying on the Blair process of making steel. In principle there is no novelty in Mr. Blair's method, which consists of deoxydizing ore and melting the iron sponge so obtained in an open hearth with pig-iron. The first step in the process has been tried over and over again by Chenot and others; and Dr. Siemens has paid an immense amount of attention to the second. The consumption of charcoal and fuel was considerable, and did not seem to be a good substitute for the combined action of the blast and puddling furnaces. Mr. Bell thus describes the Blair process:

"Mr. Blair conducts the operation in an upright retort, but circular in section, 4½ feet, in diameter, and 40 or 50 feet high. In the upper eight or ten feet, however, is inserted a metal pipe about 3½ feet in diameter, so that for this distance from the top the working space is an annulus 4½ inches across. Heat produced by burning carbonic oxide, obtained from a Siemens' producer, is applied to the outside of the retort, and heat is similarly communicated to the inside of the 3¾-feet pipe. Ore and charcoal are charged into the top of the annular space, which is thus exposed to heat from the outside and inside, instead of, as with Chenot, having the heat only applied to the exterior. The sponge is retained by Mr. Blair, as with Chenot, in the lower portion of the pipe, which is kept closed until it cools. One such retort as that described gives about 2 tons of sponge in the twenty-four hours. The difficulty which besets this and all other modifications of dealing with iron in so fine a state of division as it exists in iron sponge is its proneness to oxydation. Hitherto it seems to me the direct process, as it is termed, has met with the most success at Landore. The pig-iron, after being melted, has blocks of ore thrown in; the carbon and silicon of the bath reduce the oxyde, and the metallic iron is instantly taken up by the bath of liquid metal. Very different must be the action on sponge, which, when thrown

into the furnace, will float on the melted pig, and, being exposed to carbonic acid at a very high temperature, will, to some extent, infallibly be reconverted into oxyde. So far as I was able to learn, two parts of pig-iron and one of sponge lost about 20 per cent. in the furnace. Now, if it be true, as I have heard stated, that a mixture of wrought and pig-iron can be fused in an open hearth with a loss of 6 per cent., it follows that a considerable portion of the sponge used in Mr. Blair's process must be reconverted or reoxydized. The specimens of steel I had an opportunity of examining indicate entire success, so far as a mere question of quality in the product is concerned. There seems to be no doubt that, in obtaining the sponge-iron, Mr. Blair has made a notable step in advance of M. Chenot, and I am far from wishing it to be understood that I indicate an unfavorable opinion on the future commercial merits of the scheme."

Mr. Bell then considered the labor question, noticing the varying amounts of the wages, paid in different districts. While in one locality an iron-ore miner is paid 12s. 9d. per day, in another he is satisfied with 4s. 8d. In other districts, particularly in the South, the iron mines are worked by convict labor. The wages must necessarily be higher in the States than they are here, as the cost of living is so much greater. Mr. Bell referred at length to the question of import and export duties. He states that he is fully aware how unpopular, among a great number of the iron manufacturers, the present tariff would be—indeed, they rather seek to add to the restrictions it already imposes. In the United States itself, the opinions are very largely divided as to the benefit of protection, as applied to native industry. The protectionists frequently argue that we ourselves retained protection to native industry, until we felt that we were independent of foreign competition; and now that we no longer fear this, and require the necessaries of life for our people we are found crying out for free trade. They appear to overlook the fact that the chief opponents to free trade in England thirty years ago had as much reason to fear foreign competition as any branch of industry in the States need dread the importation of British iron. Mr. Bell gave instances of what has been the effects of production in the manufacture of iron. Soon after 1871, the price of iron commenced to rise in England. At that period, something like one-third of the metal consumed in the United States was imported from England. The change in value here at once made itself felt in America, and foundry iron was commonly sold at £10. This remarkable change led to an immediate increase in the number of blast-furnaces, many new ones being added by the end of 1873. Mr. Bell concluded his paper by dwelling at length on the benefits of free trade, and combated certain arguments enunciated to the contrary by the Secretary of the American Ironmasters' Association.

Mr. Bell expressed his satisfaction at the recompense which the meeting had given him, and stated that he had brought specimens of some of the ores he had met with in the United States, and they were in the room for inspection.

THE UTILIZATION OF WASTE STEAM.

From "The Engineer."

The number of non-condensing stationary engines in use is very large, and the discharge of their steam into the atmosphere instead of into a condenser represents a great expenditure—we shall not say waste—of fuel. Such engines are, however, seldom adopted without reasons sufficiently powerful to insure the rejection of condensing apparatus. Locomotives and portable engines for obvious reasons cannot be constructed on the condensing principle, and it will be found that stationary non-condensing engines are only used where fuel is exceedingly cheap, where water is too scarce to be used for condensing purposes, or in iron-works, where all the steam needed and more, can be raised by the heat, which would otherwise be wasted, escaping from puddling and ball furnaces. No

one thinks of utilizing waste steam under such conditions, and we shall not further refer to the subject in connection with them. Indeed, it is very difficult to see to what purpose the steam could be applied in such cases, with one somewhat limited exception—the warming of feed water—but the conditions of its employment to the best advantage in this way are well understood, and we need not dwell on them. In large cotton mills and weaving sheds considerable quantities of steam are required not only to heat the mill, but to supply the damp atmosphere requisite to the successful weaving of fine sized fabrics. In paper mills and calico printing establishments much steam is used in heating rolls, and the use of steam for warming water in brewing, etc., is very common. The question which presents itself, and which we propose to deal with here, is this: Is it better to use the steam which has left an engine for heating purposes, or to condense that steam and provide a separate boiler, or additional boiler power in some other way, to supply the steam needed for heating purposes? We happen to know that there is a curious conflict of opinion on this point, which renders it well worth discussion in these pages. We must regard the question from two distinct points of view. In the first place we have to deal with those conditions under which much more steam passes through an engine than can be used for heating purposes. This is the condition ordinarily obtaining in cotton mills. In the second place, we have presented for consideration those cases in which as much, or more, steam is required for heating purposes as for driving machinery. It will be found on examination that these varying conditions materially modify the problem to be solved.

As regards engines driving cotton mills, it will be seen that the whole question turns on the value obtained from the use of a condenser. Thus, if we suppose that 10 per cent. of all the fuel burned to make steam is expended in heating the mill, and that it could be shown that the gain from the use of a condenser represented but 10 per cent. of the whole consumption of coal by the engine, then it would be better to use a non-condensing than a condensing engine; and it will also be clear on examination, that as the volume of steam required for heating purposes augments in proportion to the power due to the condenser, so will the economy of condensing as compared with non-condensing diminish, until at last a point will be reached when it is a matter of indifference which system we adopt, while a further demand for heating steam would render it better to abandon condensation altogether. We are aware that this is opposed to the views of some engineers, who maintain that it is better in all cases to keep heating and power distinct. But our views are nevertheless demonstrably sound, provided the conditions are such that the working of the engine will be no more affected by the use of the steam in heating pipes than it would be if the steam were discharged directly into the atmosphere, a condition which we admit is not always obtainable. As regards cotton mills, however, it will be found that, as a rule, the quantity of steam required for heating purposes is much smaller than that given off by the engine—probably amounting to about one-sixth only. In a word, the engine rejects more heat than can be utilized, and this being the case, it is better to use a condenser than not. This proposition at first sight appears anomalous. Because an engine gives out more heat than we require, why should we refrain from utilizing that heat? The contradiction is easily explained away, as will be seen in a moment.

In order to ascertain the power derived from the use of a condenser, it is a very simple matter to take an indicator card and measure the relative areas of the condensing and non-condensing portions; or, which comes to the same thing, to measure the average pressure in each portion. Thus, for example, if we take the case of a condensing engine using steam of an absolute pressure of 75 lb. on the square inch expanded five times, we shall have an average theoretical pressure of 39 lb. From this must be deducted back pressure, say, 5 lb., allowance being made for imperfect vacuum and port resistance. The effective pressure will be 34 lb. on the square inch. If, however, the condenser were suppressed, the average driving pressure would remain unaltered, but the back

pressure would be increased from 5 lb. to about 17 lb., and the effective pressure would be reduced from 39 lb. to 22 lb. For the moment we shall regard the consumption of steam as remaining unaltered; therefore, the loss of power due to the loss of pressure represents the gain due to the condenser, which in the case cited would be about 36 per cent.; that is to say, for every 100-horse power given out by the engine with the condenser, it would without it, give out but a fraction over 64-horse power. It is extremely improbable that any circumstances could arise in connection with a cotton spinning or weaving mill in which so large a quantity of steam as that representing 36 per cent. of the whole power employed would be required for heating purposes, and, therefore, to abandon the condenser would be false economy. It may, however, be as well to state here that the engine when working without a condenser would not use as much steam to produce 65 horse power as it did when with the aid of the condenser it gave out 100-horse power, simply because the internal condensation either in the cylinder or jacket would be sensibly diminished when the frigorific influence of the condenser was withdrawn. The temperature of steam of 75 lb. pressure is 307.4 deg.; that of steam of 5 lb. pressure is 162.5 deg. The range of cylinder temperature would, therefore, with condensation, be 144.9 deg. The temperature of steam of 17 lb. pressure is 219.45 deg., and without condensation the cylinder temperature would consequently range through 87.95 deg. only. Precisely how much this circumstance would affect the quantity of steam condensed in the cylinder it is impossible to say without direct experiment, but that it would reduce the loss is beyond doubt. On the other hand, however, if the same conditions of expansion and pressure were maintained in both cases, the engine must have a larger cylinder in order to develop the required power, and a new element of waste would be introduced by the extension of the metallic surface with which the steam would come in contact. These matters are, however, rather beside the question we are discussing, and we may take it as proved that the engines used in our manufactories owe over one-third of their power to the assistance rendered by a condenser—in many cases much more—and that the most economical use to which heat rejected by their cylinders can be applied is embodied in the production of a vacuum.

It has been proposed that the exhaust steam might be utilized in heating mills while the condenser was retained. In other words, the exhaust pipe might be led up and down and round about a mill, and then return to the condenser. The steam would then be partially condensed in the pipes and partly by the jet. Such a scheme is eminently delusive. In the first place, the maximum temperature in the pipes would not exceed that due to the pressure in them, or, say about 170 deg.; in the second, back pressure would be occasioned by the resistance of the pipes and their bends; and lastly, it would be practically impossible to maintain all the joints in such a heating pipe air-tight. In one word, we should have a bad heating apparatus and a wretched vacuum combined. It would be waste of time to discuss this aspect of the question further.

There remain for consideration cases in which it is essential that large volumes of high-pressure steam shall be used in manufacturing operations, such as boiling pulp for paper making. Whether the supply is or is not to be had from the exhaust pipe of an engine depends altogether on circumstances. The total quantity of heat utilized by a steam engine represents so small a proportion of the whole heat contained in steam, that it is certain steam intended for heating purposes will lose little if it is first used to drive an engine. Cases may arise in which steam of a total pressure of, say, 70 lb. on the square inch is required for some manufacturing purpose. Now the consumption of fuel in producing 100 lb. steam is practically the same as though the pressure were 70 lb., and it will be very good economy to generate steam of the higher pressure named and pass it through a steam engine, which will then play the part of a reducing valve, and give out all the power due to a pressure of 30 lb. on the square inch. The engine will, it is true, work against a back pressure of 70 lb., but no one looks for economy here. As the steam

must be had in any case, it is as well to get all we can out of it, and in this way in many works from five to 50-horse power might be had, in one sense, for nothing. Under such conditions as these, the cases we have named, in which engines are worked with a heavy back pressure, become perfectly legitimate examples of the utilization of waste steam. So long as the pressure of the steam required for boiling or heating is moderate, but still considerably above that of the atmosphere, it is good policy to use strong boilers, and carry the pressure high enough to work an engine; but this rule will only apply, as we have already pointed out, in another case, when the whole volume of steam required for heating is much greater than that which would be rejected by the engines. In few words, when the primary use of steam is to heat, then the condenser may be suppressed; when the primary use of steam is to give out power, then the condenser cannot with advantage be dispensed with.

A somewhat complex case is presented when the final pressure in the cylinder of a condensing engine is greater than that of the atmosphere. Under such circumstances it is obvious that more steam remains in the cylinder at the end of the stroke than is required to produce a vacuum. The surplus may be utilized for heating purposes in many cases with advantage. On some of the American river boats it is employed very ingeniously to urge the fires. The moment the exhaust valve opens, the steam, of perhaps 30 lb. pressure, escapes in part through a suitable secondary valve, and rushing up the chimney creates a draught. The secondary valve instantly closes, however, and in doing so opens a free communication with the condenser, to which about one-half the whole volume of steam goes, the remainder urging the fires as we have said. By a somewhat similar arrangement the steam could obviously be used for heating purposes. It must not be forgotten, however, that it is very bad economy under most circumstances to discharge steam of 30 lb. pressure either into the air or a condenser.

THE PROTECTION OF BUILDINGS FROM LIGHTNING.

By R. J. MANN, M.D.

From the "Journal of the Society of Arts."

When a lightning discharge falls from a charged cloud to the earth, it of necessity takes the line of least resistance that is open to it, whatever that may be, and if that line lies along sufficiently large and absolutely continuous metallic substance, the effective resistance to its passage is so small that no mechanical violence, or heating effect of any consequence ensues. This, therefore, at once indicates what the first expedient in providing artificial protection from mechanical injury must be. A continuous rod of good conducting metal must be carried from the top of the building to the ground. Then when the stroke of lightning chances to fall upon the building, it goes by the easy way, and flows harmlessly and silently through the metallic rod to the earth, and the less perfect conducting materials of the house, such as bricks, mortar, cement, and wood, are not touched. In order, however, that this desirable result may be brought about, it is essential that the metallic rod shall be large enough to carry quietly and harmlessly the largest discharge that may have, under any circumstance, to pass through it. As a rain-water pipe must be made large enough to carry safely away the largest rainfall that can occur, if flooding is to be avoided, so the lightning conductor must be made large enough to carry the heaviest lightning that can strike. And it is even more important that this should be secured in the case of lightning than in the case of rain, because an overflow of fire is a more serious matter than an overflow of water. Some elec-

tricians consider that an insufficient lighting conductor is better than none at all, because there have been instances again and again where buildings have been saved from mischief on the discharge of lightning, although the lightning conductor that has effected their protection has been burnt up and destroyed. As in such cases, however, a new lightning-rod has to be immediately supplied, it would have been obviously better that the conductor of double capacity should have been erected in the first instance. The author of this paper must also add that he has some reason to look upon the conclusion itself with doubt. There is always danger from fire if a lightning conductor of insufficient dimensions happens to be carried along near combustible materials. The lightning stroke is certainly more likely to fall where a lightning conductor, of whatever kind, is placed than it would be if there were no such appliance. The lightning conductor, in such circumstances, may be "the slight acquisition of power which destroys the tottering equilibrium; the last straw which breaks the camel's back;" alluded to by Mr. Preece. There certainly is as much danger in the interpolation of a lightning-rod in such tottering equilibrium as there would be in "a horseman galloping along over the ground." What the damage is that a conductor of insufficient size may effect is well illustrated in the practice of firing charges of gunpowder in mines by the platinum fuse. A fine wire of platinum is made part of a current of electrical communication in the midst of a charge of gunpowder. When a current of electricity is passed through the wire it becomes red hot, on account of not having sufficient size to convey the electricity without derangement of its molecules, and the red hot wire fires the gunpowder. If the platinum wire had had the thickness of a pencil, instead of a hair, the same charge of electricity would have passed without the explosion of the gunpowder. Another very telling illustration is supplied by the not uncommon occurrence, where a small soft metal gas-pipe is attacked by a powerful discharge of lightning, and the gas-pipe is fused, and the gas set light to. What the dimensions in a lightning conductor are that would fulfil this essential condition of giving sufficient capacity for the safe transmission of the largest possible discharge is yet an unsettled question. In his excellent monograph already alluded to, Mr. Preece argues that a No. 4 telegraph wire of galvanized iron, which is a quarter of an inch in diameter, is sufficient for the protection of most dwelling-houses, because No. 8 wires, of only half this capacity, are found practically to protect telegraph posts from damage by lightning. It is, however, most probable that in the case of telegraph wires a lightning discharge is distributed among several of these protectors, as several are brought into the system by the conducting telegraph wires above. Mr. Preece alludes to two No. 8 wires having been fused and destroyed by lightning in one season. M. Arago gives the case of a chain 128 feet long, formed of successive rods of iron, one quarter of an inch in diameter, which was fused through its whole length by a lightning discharge. On the other hand, rods of iron, three-quarters of an inch in diameter, have been known to convey very powerful lightning strokes to the ground harmlessly and safely. In the instructions of the "Académie des Sciences," drawn up by Gay-Lussac and Pouillet, 1823 and 1824, a square iron bar, three-quarters of an inch in diameter, was adopted as ensuring ample capacity for all practical purposes. An iron pipe, having the same sectional mass of metal, is better than a solid rod, because the electrical force is transmitted by the surface of the conductor, and a pipe obviously has more surface than a solid rod of the same relative mass. Galvanized iron is better than uncoated iron, in the first place because its surface is protected against rusting; and in the second place because the zinc conducts with three times greater facility than iron. A rope of galvanized iron consisting of 42 strands of sixteenth of an inch wire is a very convenient form of conductor, on account of its ready flexibility, for purposes of conveyance and adaptation to angles and irregularities of a building, and on account of the long stretch that can be made in continuous lengths. If a conductor is made of several pieces, it is indispensable that those pieces

should be joined together by absolutely perfect metallic union, or there will be greatly increased resistance to the passage of the electric force in consequence of the gaps. In strands of galvanized iron the galvanic surface affords a very easy path for the electricity, and the iron core is a stubborn metal in reference to heat, and not readily destroyed. A 42-strand wire rope of the character that has bee n described affords as much surface, and is in all respects as good a conductor as a strip of stout galvanized iron four inches broad. Copper is a five times better conductor than naked iron. A rope of copper wire, one-sixteenth of an inch thick, and with 28 strands, would be as efficient as a galvanized iron wire rope of 42 strands. Dimensions of this value are recommended, because they are unquestionably equal to any demand that can be made upon them, and because there is yet some measure of uncertainty in regard to the possible intensity of the electrical discharge in exceptional cases. It may, perhaps, be necessary to point out, in regard to this particular bearing of the subject, that the sole reason why telegraph engineers incline towards conductors of smaller capacity is that reduction in cost virtually increases the number of lightning conductors that are used. This is a very important practical consideration. But, in the face of it, and after patient and long-continued weighing of the whole subject, the author of this communication, in his experience as a lightning engineer in South Africa, notoriously a favorite haunt of the thunder storm, adopted the 42 strand rope of sixteenth of an inch galvanized iron wire, and never found any reason yet to regret his practice on this point. The provision is ample for buildings of considerable elevation. The mistake of employing too small a conductor is a very common one. Within the last few weeks the author of this paper himself, in company with his excellent friend, the secretary of the Society of Arts, came upon a lightning conductor attached to a very handsome recently restored church in the vicinity of London, in which a single very small galvanized iron wire was used, where a lofty spire was part of the structure, and where, apparently, the thin wire passed down the face of this spire along a casing of wood shingles. The author submits that if this is not one of the "last straws that might break the camel's back in the circumstance of a tottering equilibrium," it ought to be. The advantage of copper, in contrast with iron, for employment as a lightning conductor, is simply that it heats less easily under an electric discharge, is very stubborn to melt, and that it is the best of all conducting substances. Its disadvantages are, that it is much more costly than the galvanized iron conductor which furnishes an equal facility of passage, and that, as a metal, it undergoes a molecular change, from the frequent passage of strong currents of electrical force, which materially affects its conducting power. It must also be remarked that copper is a very much better conductor than brass. Copper costs about one-third more than brass, but it transmits electrical currents eight times as well. Messrs. Sanderson and Proctor, of Huddersfield, and of 18 Queen Victoria Street, have recently contrived a copper tape, or strap, for lightning conductors, which costs about one shilling the foot, and which is so flexible that it possesses in a very considerable degree the advantageous properties of rope. It can be bent round the inequalities of a building with the utmost facility, can be manufactured in continuous lengths to any extent, and can even be coiled for convenience of transport. This copper tape is three-quarters of an inch wide, and an eighth of an inch thick, and therefore contains a sectional area of a little more than a tenth of a square inch of solid metal. This will most probably be found to be ample for all ordinary purposes, and it can, of course, be readily doubled in any case where lofty buildings have to be protected.

The French electricians, who are unquestionably very high authorities in matters of this class, commonly employ metallic ropes, in preference to bars, for the main stretch of the conductor, because they possess a larger sectional area than solid rods of the same diameter, are more easily placed, and adapt themselves to irregularities of structure without the trouble of forging, because they can be readily made of any continuous lengths that can be required, and, in the case of iron, can be easily galvanized, and be-

cause they are so supple and more manageable. They consider that an iron cable should have a diameter rather more than twice and a half that of copper cable (27.3 millimetres against 1 centimetre) to have the same efficiency. M. Callaud, an eminent French electrical engineer, who has very recently printed an excellent book on the "Paratonnerre," records that a rope of copper, four-tenths of an inch (one centimetre) in diameter, employed as a lightning conductor at the church of Sainte Croix, at Nantes, and which was made of seven strands, having each seven threads of wire of a gauge of 0.039 of an inch (one millimetre) in diameter, had certainly transmitted several very heavy electrical discharges without suffering any injury in its own substance, and that a similar rope of one-fifth smaller diameter (eight millimetres) previously employed had been injured by lightning discharges. Copper bars a fifth of an inch (exactly five millimetres) have been known to be as much injured by a single storm as by ten years of exposure and rust. M. Viollet Leduc, on the other hand, states that copper ropes seven-tenths of an inch (eighteen millimetres) in thickness were burned at Carcassone. From a consideration of these facts and some others of a similar character, the French electricians of the present day employ ropes of copper from four-tenths to eight-tenths of an inch (one to two centimetres) for each 82 feet of height. Mons. R. Francisque Michel, who has printed an interesting notice of the faulty state of the lightning defence of the public monuments of Paris, with some allusion to the views of M. Callaud, in *Les Mondes* of October, 1874, considers that a rope of galvanized iron wire should have a diameter of eight-tenths of an inch, to afford efficient protection under ordinary circumstances. M. Callaud prefers that metallic ropes should be constructed upon hempen cores, on account of the greater pliability which this contrivance gives. It has been already observed that lightning conductors require to be of larger size in proportion to their length. The law which rules this proportion is simply that the facility of electrical transmission in any conductor is in the exact ratio of the co-efficient of the conductibility of the metal of which it is composed, multiplied by the number representing the section of the rod, and then divided by the number representing its length. The durability of any rod is, in general terms, in proportion to the square of its diameter. M. Melsens, a high French authority, prefers that there should be several conductors of small size rather than one large one; and it is at any rate generally agreed that a large building should be furnished with several conductors, and that when several conductors are combined into one stem, that stem must be of a size sufficient for the safe transmission of all the electrical force that can be furnished to it by the contributory branches.

If it so happens that metallic cables have to be joined, the individual wires of the connected ends must be untwisted, and spliced or mingled together, and then be bound tightly round with wire in such a way that the whole can be dipped into melted solder, or solder be carefully run in over a fire. Cables may be satisfactorily connected with rods by turning a spliced loop upon their ends in this way, and by then binding this loop in upon the rod by means of strong screw nuts. Monsieur Michel, in speaking of the need of renewing the efficiency of the public lightning conductors of Paris, makes the excellent practical suggestion, that the ends of rods requiring to be spliced in continuous electrical communication should have plates of soft lead firmly nipped in by screw power between the ends that are to make contact, the entire joint being afterwards enclosed in a sufficient investment of solder.

The disintegrating energy of an electrical discharge is mainly expended upon the extremities of a conductor. It effects the most marked molecular disturbance on the part where it first falls, where most probably the first meeting of the two antagonistic forces occurs, and where the terms of the new alliance have to be arranged, and also on the part by which it has to issue from the conductor to the ground—the great natural reservoir of the reserve of the energy. On this account lightning conductors require to be expanded and amplified both at their summits and at their roots or base. The French Academie

des Sciences directed that the top of the conductor should be a bar of iron two and a quarter inches in diameter, whether square or round, tapering up to a blunt conical copper point, shaped to an angle of thirty degrees. The pointed termination of the conductor is a matter of some practical consequence, because it establishes a slow and gentle discharge of an accumulation of electrical force at high tension, as is illustrated in the ordinary experiment where the charged conductor of an electrical machine is quietly discharged by the presentation of a sharp needle to it. De la Rive held that a metallic ball was quite as efficient for an upper terminal as a point. But when a great number of lightning-conductors are brought near together, as in protecting the buildings of an extended town, there is no doubt that if they are pointed at the top they serve to saturate an approaching cloud, and to deprive it of its sting before it comes within striking distance. After the city of Pietermaritzburg, in Natal, had been largely supplied with pointed lightning-conductors, under the author's fostering influence, the actual discharge of violent lightning strokes within the area of the town became almost unknown. During several years the only cases that came under the author's notice were the tops of two chimney-stacks somewhat damaged, and a few lofty blue gum trees shattered.

On account of the facility with which it could be supplied by ordinary workmen, the author adopted a terminal for the upper end of the conductor in the colony of Natal, which proved very effective and satisfactory. In this arrangement the top of a galvanized iron rope was inclosed in a tube of stout sheet zinc, finished at the summit, for the sake of ornament, by a gilded ball of turned wood, above which the strands of the wire were opened into the form of a sort of brush. Each conductor, in this way, had 42 points of its own, and the augmentation of terminal capacity was secured by the addition of the external zinc tube. The tube also supplied a ready and convenient means of attaching the conductor to chimney stacks, or to other protruding parts of the building.

The especial function and power of points is very pleasingly and completely illustrated by a series of three experiments devised by M. Gavarret, Professor of Natural Philosophy to the Faculty of Medicine at Paris. He first charges the prime conductor of an electrical machine to the highest point of tension that it can contain; he then places near to it an earth-connected rod, furnished with a point directed towards the conductor, and he shows that the tension which can be produced in the conductor diminishes constantly as the angle of the neighboring point is made less. He next provides a Leyden jar that discharges itself by spark through a given neighboring point, and unscrewing this point, and replacing it by a crown of points, he shows that thenceforth the same jar will only discharge itself silently, and without a spark. He then so arranges the jar that it discharges by sparks below the plane of a neighboring terminal point, and on fixing lateral points below that plane the spark-discharges immediately cease.

Perhaps, however, the most telling proof of the beneficial influence of points in relieving the tension of an excited electric is that which is given by a very simple and pretty experiment, most easily performed. If a living man stands upon a stool with glass legs, and is placed in electrical communication with the prime conductor of an electrifying machine at work, with a gold-leaf electrometer on the table three or four yards away from him, and holds in his hand a sewing needle, with one finger pressed over the point, the gold-leaves of the electrometer show no manifestation of the electricity in the operator, until he unmasks the needle by withdrawing the finger from its point, when the gold-leaves immediately start asunder, under the influence of the stream of electricity which is poured out upon them through the point, even at that distance. Or yet, again, if a large tassel of strips of light tissue paper is made to throw its several strips out into a divergent brush, by electrifying the tassel from a machine, the tassels of the paper collapse together immediately upon unmasking upon them a needle point held in the operator's hand at the distance of two or three feet away. There is one very important result of the employment of terminal points to lightning rods which should never be lost

sight of. A lightning rod with efficient points, and in satisfactory operation, might be grasped by the hand of a living man, even when in action, with entire impunity, because, on account of the continued drain set up by the points, the rod can never assume any dangerously high tension. A conductor acting without a point, on the other hand, is in a state of very considerable tension when it effects its first discharge, and if it were grasped in the same way by a hand, would, in all probability, strike through that hand some very inconvenient and possibly painful proportion of the discharge. Conductors that have been acting silently with points have been seen to be struck by sinuous tracks of fire, indicating dangerous discharges of high tension, when they have been disarmed of their points.

Platinum has very generally been recommended for the construction of the terminal points of lightning rods, because it is one of the hardest known metals to melt, and because it is also not easily oxydized. The points are shaped to an angle of from 7 to 10 degrees at the top, and are made a trifle less than two inches (5 centimetres by the French) long. In this form they are screwed firmly into the top of a rod of copper, which is then in its turn connected with a cable or metallic bar below. The terminal rod is usually made of augmenting size as it descends, and is generally projected from 12 to 20 or 30 feet above the building that is to be protected. Platinum points are specially made for lightning conductors in Paris. They are supplied by Collins, of 118, Rue Montmartre; Beignet, of 96, Rue Montmartre; and Detouche, of 222, Rue St. Martin. The cost of a platinum point at these houses, grafted on brass, and from 50 to 70 centimetres (1.9 to 2.7 inches) long, is from 16 to 22 francs. For better finished work, with larger needles of platinum, grafted upon copper, the cost is from 60 to 200 francs.

M. Francisque Michel considers that the points may be quite as advantageously made of silver alloyed with copper, in the same way that it is when used for coining silver money, that is, containing 165 parts of copper to 835 parts of silver. Such points have the unquestionable recommendation that this alloy possesses a very much higher conducting power than platinum, which has 12 times less conducting power than silver and 11 times less than copper. Messrs. Sanderson & Proctor construct their points very neatly, by simply twisting the copper tape spirally at the end, after the fashion of an auger, and then filing away the termination of the flat metal into the shape of a sharp angle. The entire terminal is also glided over the copper to the extent of eight inches. This kind of point has the very obvious recommendation that it forms a continuous portion of the actual rod, and needs no joining or attachment.

The French electricians strongly recommend, upon the ground of the experiments of Professor Gavarret, that the lightning-rod should be terminated by a cluster or a crown of points, instead of by one alone, and M. Callaud has given two sketches, in his treatise, of forms of terminal points that have been adopted in France, in one of which a circle of ten points radiates at an angle of 45 degrees round the base of the principal terminal, which rises some inches above them; whilst in the other a kind of plume of points feathers out from the base. M. Beignet, of the Rue Montmartre, exhibits a model of the multiple point which the French electricians most affect. Mr. Francis, of Southampton Street, Strand, constructs a very simple and efficient multiple point of copper. The Hotel de Ville at Brussels, which is a very large building, and which has been furnished with lightning rods upon a very complete scale, by M. Melsens, a distinguished Belgian electrician, is literally bristling with points. It has 228 points of copper, and 36 points of iron, in its system.

The lower termination of a lightning conductor requires the exercise of even more care than its upper end, because it is less constantly and less generally under observation, and any shortcoming or mistake in reference to it is fatal to the efficiency of the rest of the arrangements, however judiciously they may have been carried out. A faulty termination of the earth connection is, of all else, the most common and frequent blunder, in relation to lightning conductors, that is made. As that is one of the terminations of the artificially provided conduct-

ing track, it must be of enlarged dimensions, as has been already explained. It must be in very intimate communication, not merely with the ground, but with the freely conducting portion of it. If a moist contact can be secured by insertion of the rope or rod into constantly damp soil, the contact need only be large enough to diffuse what is known as the electrolytic action—that is the chemical disintegration of corrosive metals at moist contact when electric currents are operative—over a fairly extended space. If the contact is made with dry earth, the surfaces must be very large indeed. The drier the material that is involved—unless it be an extended system of continuous metallic substance, such as the underground iron tubes of water and gas supplies in towns, which are among the most efficient ground terminals that can be adopted—the more expanded must be the surfaces of communication and contact.

It is worth while here to make a passing allusion to a few flagrant instances of faulty construction in the establishment of earth contacts of lightning conductors on account of the strength of the illustration that dwells in such failures. In a well known case of a lighthouse at Genoa, which was injured by lightning, and which was presumed to have been furnished with seemingly efficient protection, it was found that the bottom of the conductor had been plunged into the interior of a stone rain-water cistern, primarily constructed especially to keep out the infiltration of the sea, and therefore well adapted to prevent that moist contact with the mass of the earth which is essential to the object in view. Mr. Preece has drawn attention to a very similar case at Lydney, in North Monmouthshire, where the hollow of an iron gas tube, intended to protect the church, was inserted into the substance of a loose stone that was itself imbedded on dry pavement. One of the most sublime instances of this form, not merely of superfluous but of actually dangerous care, came under the author's own observation a few years ago, when he found in the case of a church in Norfolk, which was injured by lightning, although the tower was furnished with an apparently sufficient conductor, that the metallic rod was carried through the necks of glass bottles wherever it was attached to the masonry, and that the system of precaution was finally consummated at the base by putting the bottom of the rod into a glass bottle buried in the dry earth. But a few months since, the author undertook to see the protection of the residence of a friend in the neighborhood of Kensington Gardens, in which an exceptionally lofty house, even for that aspiring neighborhood, had to be defended. A sufficient copper rope was brought down from an iron balustrade that surrounded the summit of the roof, but it so chanced that this was left lying at the lower end on the stone pavement of a sunk basement floor, before the permanent earth contacts had been established, and that a thunderstorm suddenly burst over the neighborhood while the system of protection was left in that unfinished state. The head of the household, in the absence of his scientific adviser, was, however, equal to the emergency. He had the bottom of the rope carefully coiled away into the interior of a wooden pail, determined, most probably, that if the lightning did come down the rope, it should at any rate be kept in the pail until it could be carried away by some competent hand. In one very instructive instance, a house in Natal, which had been furnished with one of the author's galvanized wire ropes for a conductor, but not under his personal superintendence, was injured by lightning. The house was a low-hipped structure, of one story. The rope had been brought from the top roof ridge, which was of metal, along one of the hip angles, then down a corner post, and buried in the ground. The lightning, however, had perversely preferred to go down an opposite hip, where there was, so far, a metal road, and had then leaped through the wall, taking some iron sash weights of a window by the way, and shattering the brick work and doing other damage in its course. The author went down, as soon as he had heard of this accident, to investigate its cause; and the cause was simply this: The lightning conductor had been plunged into a tract of dry sand at the corner of the house. But at the other corner, by which the lightning had effected its own escape to the ground, was an old pool of water that had been filled up with earth,

but was still saturated with moisture, and still connected with ramifications of infiltrated soil. In this case the lightning, when it struck the roof of the house, had divided itself between the two routes which were offered to it, the conductor and the dry sand contact of insufficient area, and the wall, with its stepping stones of sash weights, and its abundant wet contact beneath. The proportion of the discharge which had taken these different routes was determined by the specific resistance of each way, and in the course that involved the leap through the non-conducting wall, the amount which passed was sufficient to produce the destructive disruption which occurred. All competent electrical engineers are now keenly alive to the automatic electrolytic action that is apt to take place in the earth contacts of a lightning conductor, and urge that it is not enough merely to construct an efficient lightning conductor in all its essential particulars, but that the arrangements must be examined from time to time, to make sure that no derangement has taken place. Such examination may readily be effected by making short circuits through the conductor with the wire of a galvanometer, so as to prove by the movements of the needle that the electric path is efficiently clear.

From the instant that an earth contact is established for a lightning conductor, destructive change of the surfaces of contact begins, and, sooner or later, the power of the conductor is materially impaired from this cause. This action, known as the electrolytic disintegration, requires to be constantly watched, beyond all else, and all the more because it proceeds in a region where the conductor is removed from observation by the eye, and it is most fortunate that such watching may be most efficiently and satisfactorily accomplished by so ready and convenient a means as the employment of the galvanometer. M. Wilfred de Fonvielle has indeed proposed that every lightning conductor should have an arrangement of a short circuit wire with the galvanometer attached permanently to it, in a form which he terms *Le Controleur des Paratonnerres*, and which is so designed as to be always ready for the eye of the observer. The author was once very near indeed so furnishing, at his own cost, a proof of the material need of some test and evidence of this character. He had supplied his own residence in the capital of Natal with one of his galvanized iron ropes, with the zinc tube and brush so demonstratively displayed above as to be a constant object of observation and remark to his compatriots and neighbors. The finial was placed so as to be a sort of advertisement of the enlightened practice of the owner of the house, and a standing reproof to the negligence of those who would not follow so excellent an example. The earth contact was very efficiently made, by carrying the rope along the muddy bottom of one of the streams of constantly running water that, in the old Dutch settlements of South Africa, are always found fringing the streets; and during many very severe thunderstorms the author sat in his easy chair, priding himself on the completeness of his arrangements. He subsequently, however, by mere accident, made the astounding discovery that for a considerable length of time the tail of his lightning rope had not been trailed in the wet mud, but was carefully packed away along a stretch of dry ground, under the shelter of a thick-set hedge, that served effectually to conceal its presence there. On some unhappy occasion, when the author was away, the water-courses had been undergoing cleansing and repair by the civic authorities, and the workmen, finding the metal rope in the mud, had taken considerable pains to pack it away in the drier and cleaner place in which it was ultimately discovered. If any accident from lightning had in the meantime occurred to the house, this case would certainly have lived in the annals of Natal, for a couple of centuries at least, as a remarkable proof of the inefficacy of lightning-rods, and the great lightning doctor himself would have been held to have brought down the vengeance of the clouds upon his own ignorance and presumption.

The French electricians have contrived a very excellent expedient for making an efficient earth contact. They construct a stout harrow of galvanized iron, with recurved teeth, connect this carefully with the end of the cable or rod, and then bury it, imbedded in a mass of coke, in moist earth. The cable or rod

is conducted to a suitable site for this terminal in channels of curved tiles, well filled with broken coke, or even sealed up in leaden tubes, if there are ammoniacal vapors to be encountered by the way. M. Callaud has a still more ingenious and admirable plan of effecting this purpose. He hangs at the bottom of the cable a galvanized iron grapnel, with four upturned and four down-curved teeth, and entangles these within a basket of netted wire, and then packs in this basket with fragments of coke; and the basket, coke, and grapnel are afterwards sunk into a pit or well, or buried deep in moist earth. M. Callaud prefers coke to charcoal, on account of its greater porosity and accessibility to moisture; and he has made some careful experiments to satisfy himself of the size which this earth terminal should have. According to the experiments of M. Pouillet and M. Ed. Becquerel, pure water conducts the electrical force 6,754 million times less freely than copper, and therefore, for free transmission, the earth contact, if effected by pure water, should have 6,754 million times the area of the main conducting cable or rod. This theoretical argument is, however, very materially affected by the fact that the water in the earth contains conducting principles of considerable power, and by other analogous considerations; and an earth contact of 1,000 square metres (1,196 square yards) has been fixed by the best French authorities as sufficient for all practical purposes for a conductor of copper, that is, one centimetre (four-tenths of an inch) square. M. Callaud calculates that in order to accomplish this purpose his earth-basket must contain one hectolitre (two bushels and eight-tenths) of broken coke. In order that a lightning rod may perform its work perfectly, it is obvious that there must not be any greater resistance to the passage of the electrical discharge at its earth-outlet than there is in the rod, or main channel of the discharge. Very commonly in badly-arranged lightning-rods, it is found that there is ten thousand times more resistance at the outlet into the earth than there is in the main rod of the conductor. When this altogether excellent expedient of M. Callaud's cannot be adopted, a bore, four or five inches in diameter, should be sunk sixteen or twenty feet into damp soil, into which the cable should be inserted, and then the bore should be filled round the cable with broken coke, and the whole be firmly rammed down; or radiating trenches should be cut as deep as possible in the ground, and corresponding branches from the cable be then packed into these with an investment of broken coke. M. Francisque Michel gives an unqualified approval to the attachments of the lower terminal of the cable to iron-service-pipes, whether of water or gas, in towns.

In Gay-Lussac's report to the French Academy of Sciences, in 1823, it was held that all large metallic masses contained in any building should be brought into metallic communication with the main system of conductors, and that there was no need whatever for the employment of insulating supports in attaching the lightning rod to the structures that it is intended to defend. These conclusions of Gay-Lussac's have been generally acted upon since his time, and no very marked case has ever occurred to stamp the practice that has been adopted in these particulars as radically wrong. In my own practice, in the colony of Natal, I have almost invariably acted upon them, and no single instance of insufficiency of protection has ever come under my notice in consequence of the arrangement. The point is, however, one upon which there is now some difference of opinion in high quarters. M. Callaud, for instance, in his recently-printed treatise on the Paratonnerre, insists upon the adoption of insulating supports for the rod, and unconditionally condemns the electrical communication of the rod with the metallic masses contained within the building; and he states in one part of that work that M. Pouillet has to some extent given in his adhesion to these revolutionary views. M. Francisque Michel, on the other hand, upon a full review of all M. Callaud's arguments, maintains the old doctrine that the conductor may safely be attached to the masonry of the building by ordinary staples or holdfasts, or any convenient way, and that insulating supports are of no use whatever, and that all masses of metal contained in a building should, as a general rule, be metallically connected with the main line of the conductor.

Professor Melsens, of the Royal Academy of Belgium, one of the highest Belgian authorities, contends, upon experimental grounds, that the well-known laws of derived electrical currents apply with equal force to the transmissions of electrical force of high tension, and that scattered masses of metal in any building should be metallically connected with the conductor by closed circuits constituted by contacts with two distinct points of the rod. This divergence of view among high authorities is of notable import, because it is virtually the only material difference of practice that is encountered in the treatment of this subject by well qualified scientific men, and it may therefore be very readily admitted to be an affair that yet requires a more searching investigation, and further severe question by observation and experiment. In the meantime it is of some importance that the exact bearing of the doctrine advocated by M. Callaud should be understood.

In illustration of his argument M. Callaud takes the case of an iron balcony supported in front of the window of a house at some elevation from the ground, and considers the possible result to living men and women contained in this balcony at the time of a severe thunderstorm, accordingly as the balcony is, or is not, electrically connected with an efficient lightning rod. He argues, if the balcony is connected with a lightning rod, a living person standing upon it, or leaning against its rail, is very much more likely to be struck by a discharge of lightning, than if the balcony had no such connection. In the former case, the living body is likely to be made a stepping-stone for the lightning on its way to the rod. He holds that in the case of a lightning stroke the chances are a hundred to one that a lightning rod is struck in preference to any part of a building, that if the conductor is faulty in any particular, and scattered metallic masses are connected to it, this is tantamount to attaching the hundred chances of danger to the metallic masses and to living people placed near them. He says, in effect, a satisfactory and perfect lightning rod should be so placed that it efficiently protects every part of the structure it is attached to, and that if it does this no scattered mass of metal within the building can possibly be struck by a discharge. Therefore, connection of the rod with scattered masses of metal is superfluous and useless where the rod is efficient and perfect in itself, and objectionable and dangerous when the rod is not in an efficiently acting condition. And perhaps the greatest force of this argument falls upon a fact which is very earnestly pressed by M. Callaud, that a lightning rod is a merely passive piece of mechanism, which does not give visible or palpable signs of its own derangement, like a clock, but which may furnish fatal proof of its imperfection too late, by killing the person who places unmerited and undue trust in its efficiency and excellence. M. Callaud remarks with some force: "Lightning cannot strike a structure that is well protected. If the lightning finds at the side of the Paratonnerre an electrical conductor that is superior to itself, the structure is then inefficiently defended. A Paratonnerre ought to dominate, to cover, to protect, a building, in all its parts, and in all its details, or it is better away." The gist of the whole matter, therefore, is, take care that your conductor is perfect and efficient in all its parts, and that it is in every sense adequate to the work that it is required to do, whatever may be the size of the building, and then it becomes a matter of small moment whether scattered masses of metal comprised in the building are connected with the rod or are not connected, and whether the rod is connected to the building by insulating or by non-insulating supports. M. Callaud's conclusion, however, (and it is the one upon which he states that M. Pouillet has given in his adhesion), is substantially, "Connect any masses of metal with the Paratonnerre that are of necessity removed from the occasional close presence of living people, but on no account ever connect such masses with the Paratonnerre when they may at any time have living people in their close neighborhood." Pending further investigation of this very interesting point, there can be no doubt that this distinction is a prudent and a safe one to be adopted in practice, and that it is more prudent and more required in proportion to the insufficiency of the arrangements of the conductor. Conducting masses which are connected

with the earth by less readily conducting substances occasionally give rise to a curious effect, which is technically known as the return-shock, and which is altogether a result of inductive action. When a powerfully charged electric comes within a moderate distance of them, an electrical charge of an opposite character is drawn into them by induction, but this secondary charge escapes back towards the earth the instant the inducing tension is removed. The production and character of this return shock, caused by inductive action, admits of very complete illustration by electrical apparatus. An insulated conductor of long cylindrical form, but with its glass supports only half the length of the glass pillar of a prime conductor of an electrical machine, may be placed parallel with the prime conductor, but about an inch away. The secondary conductor is then to be raised to the same height as the prime conductor, by fixing its glass pillar upon the top of a pillar of wood, a fine wire being carried from the metal cylinder to the wood. A wire is then also to be carried from the secondary conductor to the earth, but is to be so arranged that a small gap may be left in some convenient part of its course. When the prime conductor is charged positively by the machine, the positive electricity of the secondary conductor is inductively driven out through the wire and the wooden pillar to the earth, and the conductor itself remains negatively charged. But when the working of the machine is stopped, and the prime conductor is deprived of its positive charge by a touch of the finger, the negative charge in the secondary conductor is also set free from its condition of inductively maintained constraint, and positive electricity leaps back from the earth to restore its proper balance and saturation, and as it does so is seen passing as a spark through the gap in the earth-wire, because that gap affords less resistance to the passage of electricity of tension than the supporting pillar of wood. If a little gun-cotton, or some other suitable inflammable substance is placed in the gap, it is fired by the spark at the instant of the discharge. Professor Tyndall, in his lectures at the Royal Institution, shows the production of this sympathetic inductive discharge in a very magnificent form. He has a flat coil of copper wire imbedded in a mass of insulating resin, through which he can pass the discharge of the powerful battery of the institution, consisting of fifteen Leyden jars; and he has also a second flat coil similar to the first, which he can place parallel to it and about an eighth of an inch away, the two ends of the second coil being connected with a wire presenting a small gap of continuity. When the discharge of the battery is passed through the first coil a powerful sympathetic discharge rushes at the same instant through the secondary coil, and makes itself manifest by a bright flash and a loud snap in the gap of the connecting wire. The discharge of an electric cloud in this way not uncommonly produces a number of sympathetic minor discharges from neighboring bodies. The induced discharge is sometimes quite strong enough to produce mechanical mischief in resisting bodies that lie in its path. The shocks experienced by living people on the instant of a discharge of lightning, without fatal results, are generally of this character. It was to meet the case of these incidental induced charges, and the consequent "return shocks," that the expedient of connecting scattered masses of metal with the conductor was originally devised. The return shock resulting from a limited inductive disturbance may be strong enough in some circumstances to cause death by the mere arrest of the vital action of the nerve structures through which it passes, without leaving behind it any trace of mechanical violence, such as is generally produced by the true lightning stroke.

The old practice of protecting buildings from lightning consisted in erecting rods of metal upon wooden frames, near to, but not in actual contact with, the walls of the house. When the author of this article first visited Natal, in 1857, the houses in the two principal towns, that were defended at all, had independent conductors of this class, of the rudest possible kind, erected by the side of the one-storied houses upon ungainly wooden frames. The conductor was composed of an iron rod, joined in three lengths, and rudely pointed above, and it was made of three different pieces —a comparatively thick one below, and

a comparatively thin one at the top. This practice was primarily based upon an investigation which was conceived to demonstrate that all structures lying within a conical space, which had the conductor itself for its height and a breadth for its base equal to four times the height of the conductor, were safe. This estimate gives a fair approximation to a truth, but it is by no means absolute, and must not be empirically relied upon. It, however, furnishes a very good indication of the way in which the upper termination, or terminations, of the rod must be arranged. The terminal point should go some considerable distance above the housetops, and then if any projecting parts of the house extend beyond the surface of a line having, perhaps, a somewhat more acute figure than the one which has been named, other subsidiary points must be reared up from the line of the conductor above such conical slopes. Mr. Preece, in his paper, considers that the lightning conductor should only be held to afford absolute protection within a conical space in which the base is as large again as the height of the line. When, however, the general idea of the limits of this lateral protection is once clearly conceived, it becomes very easy, indeed, to render the arrangements of the upper terminals perfect for any individual case. It is only necessary that all prominent masses of metal shall be connected with the system of metallic communication, and that an addition branch of the system of defence shall be carried out whenever outlying parts of the structure get near to the conical limit of protection. This is virtually what has been done in the case of the Hotel de Ville, at Brussels, with its terminal of 264 points.

When Sir William Snow Harris, now some years ago, turned his attention to the protection of ships from lightning, he devised a plan of making the lightning conductor a part of the original design and essential construction of the ship. Now all large and well-contrived vessels are always built with the lightning rod included in their structure. It is almost incredible that up to this time the same course has not been taken with houses. It is hard to understand why lightning conductors should be objects of exceptional luxury, and rain pipes objects of daily need, and the more so when rain pipes themselves can be so easily turned by a little forethought and mechanical ingenuity into lightning conductors of the most efficient character; they only need that their joints shall be made mechanically continuous, that their earth contacts shall be perfected, that all masses of metal, with perhaps the limitation that is contended for by M. Callaud, shall be brought into metallic communication with them, and that metal terminals shall be distributed from them to the roofs above upon the principle that has been explained. Mr. Preece has thrown out one very excellent suggestion which well deserves further thought; it is to the effect that metal ventilating pipes carried up from the sewers over the roof of the house may advantageously be made part of the arrangements for protection against lightning. The familiar case of the Monument of London is continually adduced as a proof of the readiness with which the accidental features of a building may be turned to account for this purpose. The metallic emblems of flame at the top of the column are continuously connected with the ground by means of a very thick balustrade of iron that runs as a hand-rail down the stairs; the structure is 200 feet high, and towers above all neighboring buildings, and yet it has now stood within three years of two centuries without ever having been injuriously touched by the lightning.

It was conceived, until recently, that St. Paul's Cathedral had been efficiently protected in some similar way by the arrangement of water-pipes, and some supplementing of them by metallic rods, added by a Committee of the Royal Society some 120 years ago. Mr. Faulkner, of Manchester, however, found, in a careful examination made subsequently to 1872, that the system had become entirely inefficient for the purpose for which it was intended, by the formation of thick incrustation of rust on the contact surface of the rods, and by the interpolation of blocks of dry granite, some nine inches thick, in places, into the actual line of electrical conduction. The entire building has now been most efficiently protected, under the skilful direction of Mr. Faulkner, by carrying eight

octagonal half-inch ropes of common wire from the Cross, Ball and Golden-Gallery through the metal-work of the roof of the dome, and through the metal work and rainfalls of the lower parts of the building to the sewers, where the conducting strands terminate in copper plates pegged into the moist earth. In carrying out this work every important metallic portion of the building was separately tested by the galvanometer, to make sure that the electrical communication with the earth was virtually and substantially clear. The galvanometer was first made into a circuit with a metallic gas-pipe; and then the circuit was opened out, so that earth was made in one direction through the gas-pipe, and in the other through the metallic portion of the building for the time under examniation; and the test was not considered satisfactory until the deflections of the galvanometer were the same under both alternatives. In arranging methodical architectural plans of this kind it must always be carefully borne in mind that small gas-pipes of easily fusible metal must on no account form part of the connecting lines of conducting circuit. Gas-pipes are most easily fused by a stroke of lightning, and when they are so fused the gas which escapes from the extemporized orifice is invariably set light to.

One point which was expressly urged by Mr. Preece and by Captain Douglas Galton in the discussion of Mr. Preece's paper at the Society of Telegraph Engineers, should be most carefully kept in view in any structural plan matured for the protection of buildings, namely, the including of all fireplaces or stoves, and soot-blackened chimneys in the system of connected construction. To adopt Mr. Preece's own statement of this need: "It must not be forgotten that a chimney lined with a thick layer of soot, up which a current of heated air and volumes of smoke are ascending, and terminated by a mass of metal (the grate), is an excellent but dangerous conductor, for it ends in the room, and not in the earth."

Since the first preparation of this paper, two pamphlets by Messrs. Gray & Son, of Limehouse, have come into the hands of the author, which are valuable and interesting on account of the details which they contain of a considerable series of instances of damage from lightning. Mr. W. J. Gray, of this firm, was originally concerned with Sir Wm. Snow Harris in perfecting his plan for protecting ships, and obviously possesses a large amount of practical information in regard to accidents that have occurred. Space now only serves to say that the Messrs. Gray endorse the practice of connecting all metallic masses in a structure with the main line of conduction, and especially urge the surrounding of all prominent objects, such as the tops of tall chimneys and church towers, with continuous bands of copper brought down into direct connection with the discharging rod.

The great length to which this paper has already extended itself alone prevents some allusion being here made to the views of Professor Zenger, of Prague, who advocates the use of circular zone-like or ring-shaped conductors, embracing within their span the objects which are to be defended from injury.

There is no sufficient ground for the popular idea that accidents from lightning are of such rare occurrence that it is scarcely worth while to incur the trouble and cost which artificial protection involves. The figures of the statistician prove that accidents are very frequent indeed. The Escurial in Spain has been set fire to four times by lightning in less than three centuries. As many as 1,308 persons were ascertained to be killed by lightning in France between 1835 and 1852. Some time ago the mean number of deaths from lightning in each year was marked at 3 in Belgium; 9 in Sweden; 22 in England; 50 in the United States of America; and 95 in France. M. D'Abbadié records the destruction of two thousand sheep by a single discharge of lightning. Mr. Preece tells of 897 telegraph instruments injured by lightning in the first six months of 1872 in a staff of 9,475 instruments. Mr. G. J. Symons, one of the secretaries of the Meteorological Society, has given, as the list of accidents that he had ascertained to have happened during two severe storms in June, 1872; 10 deaths and 15 cases of injury to human beings; 60 houses struck and 15 burned down; and 23 horses or cattle, and 99 sheep killed.

It need scarcely be said that many accidents also occur every year from lightning, over and above those which get publicly spoken of or placed on record. In large towns damage to property is more frequent than destruction of human life, but in the open country destruction of life is the more frequent occurrence. In the face of figures like these, and of the fact of the slowness of man to avail himself of the ready defence which science places at his command, unfortunate humanity certainly stands very much in need of the consolation which the physiologist affords when he tells us that all danger from lightning is past when the flash of the electrical discharge is seen, and when he further states that when men are killed by lightning they are dead before they have time to know anything about the fact, or indeed to be conscious of the fatal blow; a conclusion by the way that is strikingly corroborated by an unintentional experience of Professor Tyndall's, who upon one occasion passed the full charge of the Leyden jar battery of the Royal Institution, by accident, through him, and was perfectly unconscious of any shock. It is something, at any rate, to have this comfortable assurance when the sense of neglected opportunity comes over the mind in an exposed situation and in an unprotected house during a severe thunderstorm. But it is humbly submitted, as an appropriate last word of this paper, that to men of well-regulated minds a good lightning conductor may, in such emergency, be found to be an even greater satisfaction and comfort.

THE IRON AND STEEL INSTITUTE.

Address of the President, Mr. W. MENELAUS.

Abstract from "The Engineer."

My first duty is to thank you for the very high honor which you have conferred upon me in electing me to fill the office of President of the Iron and Steel Institute. As an iron maker my mission has been to bring into profitable use the valuable inventions of Bessemer, Siemens, and others, and to apply the scientific research of men like Mr. Bell to the improvement of old and new processes.

So much has been said, and well said, by my predecessors about the history, the position and the prospects of English iron making, that I propose on this occasion to confine my remarks mostly to the manufacture of wrought iron and steel, and the application of the latter to constructive purposes. For the conversion of pig into wrought iron, the rotary puddling machine, in one or other of its forms, has occupied the attention of iron makers for many years, and various attempts have been made from time to time to perfect the machine. When, under the auspices of this Institute, the Danks machine was introduced into this country, success seemed certain; several machines were erected, mostly at and near Middlesborough, but they seemed to have failed, chiefly from defects in mechanical construction. These defects have, I am told, been rectified, and several important improvements have been made in the construction and mode of working the machines. To Messrs. Hopkins, Gilkes & Co., is due the credit of having first introduced and practically tested these machines in England. The Erimus Company followed, and erected extensive works, in which the Danks machines alone are used. Certain difficulties were met with, and no doubt, for a time, some disappointment was felt; how these difficulties were met and overcome is fully explained in an interesting communication from Mr. John A. Jones, which I will read:

A year ago the writer stated in London, what were at that time considered to be the chief drawbacks to the success of rotary puddling. They were stated to be the education of the men and the removal of prejudice from amongst them; the difficulty with the fettling of the furnace, and the mechan-

ical weakness of the Danks machine. It was quite evident that unless the company could procure a certain quantity of iron from each machine in a given time and in a regular manner, rotary puddling could not favorably compete with hand puddling, so far as the cost of puddled iron was concerned. The obstacles were in chief as stated above, and to the removal of these the company devoted their attention. The education of men, which includes the change from a positive state of indifference to that of active assistance, has given more trouble and anxiety than was anticipated; and to this day we have not received that active co-operation from the men which is necessary to the complete success of rotary puddling. At the same time much progress has been made in that direction, and it is earnestly hoped that in a short period we shall receive that assistance which will enable us to do better than has hitherto been done. The fettling of the furnace, and the materials used for the same, are no longer questions of difficulty, and in this respect we have no drawback. We line the furnace after each heat with best tap, pottery mine, purple ore, and Spanish ore; suitable proportions are mixed in a grinding mill, and then used in the furnaces. Fettling can be procured suitable to any district where the difference in the quality of the pig iron mostly necessitates a variation in the fettling ingredients. With regard to the mechanical imperfections of the Danks machines, they have been of a serious character. The repairs have been very costly, and the loss of output, by reason of frequent stoppage, has affected the cost of production most unfavorably. It became apparent that unless the mechanical construction of the furnace was such as to insure regularity of work, it was hopeless to expect satisfactory results; and the attention of the directors was devoted to this necessity. It was at last agreed that new furnaces of a different construction should be adopted, and to that end one was erected as an experimental furnace. This furnace has been at work for nearly two months. It is a double-case wrought iron furnace, hooped with steel, and is water-jacketed. There is a constant flow of water to and from the water space, and the water at the outlet pipe is kept at from 80 deg. to 100 deg. Fah. — in fact, perfectly cool. This double-cased furnace has maintained its mechanical accuracy, which it is almost impossible that a single-cased furnace can do, owing to the effects of expansion and contraction. The firing of the new furnace is done in the usual manner. It will not be necessary for me to describe in detail the improvements of this machine; let it suffice that it has been designed and constructed, after all the weak points of its fore-runner have been carefully considered. The directors are so satisfied with the work done by this machine that they have ordered five more, and six sets of new engines to drive them. In designing the engines the same amount of care has been taken. They are over-head double-cylindered engines; the wearing parts have been carefully designed, and nothing in strength or in the detail is left unprovided for, so as to insure continuous and satisfactory working.

In manufacturing puddled bars at the Erimus Ironworks, the pig iron is first melted and refined in one of Thomas' cupolas. The refining is done during the smelting process, and is accomplished by simply mixing scrap iron and ore in the charges. The perceptible effect it has upon the iron is that where the charge is exclusively of No. 4 forge grey pig, the fracture becomes that of white or refined iron. The chemical effect is that a portion of the silicon and phosphorus is removed, and it is to this end that the refining is done, so that there will be as little action as possible upon the lining of the furnace. The effect of using refined iron is very marked. We do not perceive any melting out of fettling *per se;* but what is used is reduced, and thus adds to the yield. Again, the refining of the iron does not necessitate the fettling of the furnace so often, whereby much economy is effected in the fettling used, and in the time which is devoted to puddling. We charge entirely with melted and refined iron, and the weight of our present charge is 14 cwt., which, when the new furnaces are erected, will be increased to a ton. The Cleveland forge iron, which is almost exclusively made from a foundry burden, is very silicious. It

holds from 2 to 3 per cent. of silicon. It is obvious, therefore, what an evil effect this pig iron has upon the fettling; and a portion of this is removed, as is stated, by refining. In Cleveland scarcely any grey forge is made from a forge burden, but it is derived from an attempt at foundry iron, and the finished iron-making suffers severely from this. No heat takes more than thirty-five minutes to puddle. The heat is removed in a single ball, and squeezed or shaped into a piece about 14 ft. long by 15 in. diameter. It is then cut up at the same heat, and taken to reheating furnaces, where it is reheated, hammered, and rolled into bars. The Erimus Company are now making angles, bulbs, bars, and tees, with no other iron than Cleveland. Three relays of men are employed at the machines, and work eight hour shifts. It is expected that each furnace will work six heats in the eight hours, and this is regularly done unless some breakdown or accident interferes; and with the old machines those breakdowns are unfortunately only too frequent. At the present time the company are working six furnaces, and they average nearly 300 tons per week of puddled bar, thus giving an output of 50 tons per furnace per week. The present consumption of coal is for actual puddling 9½ cwt. to the ton of bars. Of fettling (half bought and half from first heating or mill furnaces) 9 cwt. to the ton of bars. The yield of bar from pig is 20 cwt. of pig to 20 cwt. of bars. The whole quantity of coal used to the ton of bars, including reheating, is under 20 cwt. The price we pay the puddlers is at present 3s. 2½d. per ton long weight, they paying their own under-hands. The whole wages of every kind, including cupola-refining and re-heating, is under 20s. per ton of bars. The question now arises—Are we satisfied with a production of 300 tons per week from six furnaces; and is there any prospect of increasing that quantity? The answer is—We are not satisfied; and there is every prospect of the quantity being increased to 500 tons per week from six furnaces. To this end new machines and engines are ordered, capable of taking one ton charges; and the tools are being remodeled to handle the heavier charges. The experiment of working a ton charge has frequently been made, and the time required for puddling never exceeds forty minutes. The number of heats will be the same as at present—viz., six in eight hours; and it is simply by the increase of the weight of the charge that the quantity will be raised from 300 to 500 tons. The actual puddling of the six heats will take up four hours, leaving the other four hours for fettling, repairing, cleaning grate-bars, etc. We find that it takes the same coal to puddle a ton as to puddle 14 cwt., and as the time consumed in charging, drawing, fettling, and squeezing, will be the same as at present, it is obvious that the increase of the charge to a ton is the proper course. We have no doubt that we shall be able to bring the consumption of coal for puddling down to 7 cwt. to the ton of bars; and the whole of the coal consumed in the puddling department to 15 cwt., and we anticipate that the wages will not exceed 15s. on the ton of bars, which will include all labor charges in the puddling department. The new furnace at the Erimus Works, when worked experimentally, gives results much better than are stated here. The foregoing figures give the average results of our working in a regular manner.

(Signed) J. A. Jones,
Managing Director.
The Erimus Company Limited.

The Erimus Ironworks.

Make at Forge, four weeks ending March 27th, 1875.

	Tons.	cwt.	qr.	lb.
Week ending 6th of March; number of furnaces, 5.....	193	2	1	15
Week ending 13th of March; number of furnaces, 6.....	282	7	1	5
Week ending 20th of March; number of furnaces, 6.....	298	0	3	0
Week ending 27th of March; number of furnaces, 6.....	275	5	2	10
	1048	16	0	0

In thirty-six working days of twelve hours.

Coals consumed for Puddling alone, four weeks ending March 27th.

	Tons.	cwt.	qr.	lb.
Week ending 6th March	92	5	0	0
" 13th "	116	10	0	0
" 20th "	141	1	2	0
" 27th "	124	8	0	0
	474	4	2	0
		cwt.	qr.	lb.
Coal to a ton of bars on puddling alone		9	0	6

Certified to be correct, and taken from our pay books. JOHN A. TOOD, Pay Clerk.
J. A. JONES.

The members of this Institute have taken such a deep interest in the Danks method of puddling, that I believe you will all be pleased to know the precise position in which it now stands, and we ought to be very much obliged to Mr. Jones for the very explicit statements which you have just heard. Mr. Heath, with his usual enterprise, was one of the first to take up in earnest the Danks system of puddling. Mr. Heath informs me that he has had six Danks furnaces at work for some time, and has four additional furnaces ready for work. He is rolling from Danks blooms, in the ordinary forge rolls, 16 in. bars, 24 ft. long. Mr. Heath states that he is making these bars more cheaply than by the old puddling process, to say nothing of the saving in waste in cutting up long bars as compared with bars one-fourth the length. Mr. Crampton, who has made a long series of experiments on mechanical puddling, having been at work on the subject over five years, has produced some very excellent results as to quality of metal; and he assures me that his experimental machine at Woolwich is workiug very economically, and that it will bear the test of continuous work; to use his own language, "The furnace is fitted to stand the rough usage to which such a machine must be subjected in ordinary iron works, and it involves a minimum expense for wear and tear, and for general repairs."

Sir John Alleyne has also worked at this problem of mechanical puddling. He is experimenting with the Siemens rotator and also with a modification of Maudslay's machine. Mr. Reynold Alleyne thus describes the latter machine as modified by his father: "We are now working my father's machine with Siemens' gas furnace, and also heated by direct combustion in the ordinary way. The machine consists of a pan, which rotates on a vertical axis, and the puddler, which is fixed overhead, and which works the rabble to and fro at right angles to the front of the furnace. When the heat is ready to ball up, the puddler is stopped, but the pan continues to revolve. The work of balling is done at the door, and it is never necessary to reach across the furnace. In the gas furnace we charge five heats of 6 cwt. per shift. The waste is 2½ to 3 per cent. The waste in the direct combustion furnace, with the same charges, is 10 per cent.; showing the advantage of using gas in place of solid fuel. The two furnaces are worked by one puddler each, and a boy to look after the machinery of both furnaces." Sir John himself expresses an opinion in favor of the pan, or "soup plate," as he calls it, heated by Siemens' gas furnace." At our annual general meeting in May of last year, the Pernot furnace was described. The furnace is the revolving pan with the axis inclined, as invented by Maudslay; but M. Pernot has made an important improvement on Maudslay's furnace. He has mounted the revolving pan on a carriage on wheels, and it can be withdrawn from the puddling chamber for repairs. Mr. Snelus, who has just returned from a tour through the French works, informed me that he saw three Pernot's puddling furnaces at work at Messrs. Petin Gaudet's works. They were working one ton charges of iron, mostly white, and each charge produced 18 cwt. of puddled bars. The fuel was slack coal, of which they use 14 cwt. to the ton of puddled bars. The fans are fettled with Motka iron ore, about 2½ cwt. being used to the ton of iron made. Each furnace produces about 4 tons of puddled bars in twelve hours. Two puddlers at each

furnace ball up the iron. Mr. Snelus adds that the furnaces have been at work some time, and that they seemed in fair working condition. In the manufacture of steel, we are making in England, by the Bessemer process alone, ten thousand tons per week, and the production is rapidly increasing. Various mechanical improvements have been made, which enable us to turn out larger quantities. In some cases as much as one thousand tons per week has been made from a pair of converters. When Mr. Bessemer first designed his steel-making plant, his idea was to run the iron direct from the blast furnace into the converters. His first apparatus, on a large scale, was erected at Dowlais, where it was put down in front of a blast furnace, and the iron was run direct from the furnace. The experiment, for reasons quite independent of the mode of charging the converter, was not successful; nevertheless, we in England have ever since been content, for no sound reasons, I think, to melt down the pig iron at considerable cost, instead of running it straight from the furnace. In most cases in France, and in some other countries, the iron is run direct from the furnaces; and I see no reason why in England we should not revert to Mr. Bessemer's original plan, and so save all the cost and waste of melting. Of course, it will require careful management at the blast furnaces; but with our pure fuel, excellent ores, and with a plentiful supply of pure foreign ores as a mixture, I see no difficulty in carrying out this economy in the production of Bessemer metal. Mr. Bessemer informs me that, under his advice, in one of our leading steel works they are about to run the iron direct from the furnace; to use his own language, "They will use my process of further carburising 20 tons of metal at a time in a hot vessel, mounted on wheels and running on rails to the converters; the metal will keep hot for several hours in this vessel. Less carburetted metal may be made in the blast furnace, and the necessary quantity of carbon added at almost no cost." Another member of our Institute, Dr. Siemens, has worked out, in a different way, the same problem, with much success. The idea of producing steel by melting together cast and wrought iron, or cast iron and ores, in suitable proportions, is, of course, old, but it was not until Mr. Siemens brought his scientific and practical knowledge—and a no less wonderful amount of perseverance—to bear on the subject, that the mode of making steel, known as the "Siemens-Martin process," was perfected. The most important element in the successful accomplishment of the Siemens-Martin process is unquestionably the "Siemens, or regenerative, gas furnace." By its means, any degree of heat, even to the fusing point of the most refractory materials, can be obtained economically and without resorting to air-blast or cutting draughts, and these conditions are indispensable where we have to deal with a bath of mild steel, exposed to the surface action of the flame. An adequate idea of the elevated temperature obtainable in these furnaces may be formed by considering that near the end of each operation the furnace contains from five to six tons of almost chemically pure iron in a state of perfect fluidity, beneath a covering of slag, several inches thick. Mr. Siemens estimates this temperature at 2200 Cent. Mr. Siemens states that he is now erecting furnaces of 10 tons capacity, which will be capable of producing 20 tons of steel in twenty-four hours if pig and ore be used, and 30 tons if pig and scrap be employed. The steel made by the Siemens-Martin process is used for all the purposes to which soft steel is commonly applied. It is used in England for casting screw propellers, and for various other high-class steel castings. At Creusot a mild steel is produced by this process containing only 10 per cent. of carbon, which is used for piston rods, and other parts of engines, for boiler-plates, and, more recently, for shipbuilding. As we know, Mr. Siemens has for some years been engaged on a method for producing malleable metal direct from the ore. The process consists in treating ore with reducing materials in a rotary furnace, under the influence of a reducing atmosphere, accompanied by the intense heat produced by his regenerative gas furnace. His object is to produce either bar iron or metal from the bath furnace direct from the ore in one operation, and at a greatly reduced expenditure of fuel; but, although this method has, as I under-

stand, succeeded experimentally, proof is as yet wanting of its practical success on a large scale. M. Pernot has applied Maudslay's revolving pan, not only for puddling, but also for making Siemens-Martin steel. The furnaces produce over ten tons of steel per shift of twelve hours. The waste is said to be 7 per cent., and the consumption of fuel 7 cwt. to the ton of ingots made. The cost of labor is stated to be 4f. per ton. This furnace is worthy of the attention of English steel-makers, and is, I think, destined to play an important part in the manufacture of Siemens-Martin steel. I have said that Mr. Bessemer has given us what may be fairly called a new metal, and a wonderful metal it is; and that, by an entirely different process, Mr. Siemens has enabled us to produce the same metal also at a moderate cost, and with all the excellent qualities of Bessemer metal. For a considerable period I have been engaged in making Bessemer and Siemens-Martin soft steel, and I claim to know something of the excellences of both. Speaking as a manufacturer, I am of opinion that, with our present knowledge, in no other form can iron or steel be produced at the same cost, and of a quality equal to that of the steel made by the Bessemer and Siemens processes. Having a high opinion of the value of the material for constructive purposes, and seeing with how much success it has been applied on our leading railways, and how it has almost completely superseded the old forms of wrought iron, where it has been introduced with skill and a full knowledge of its properties, I wonder, and wonder much, that many of our leading engineers and shipbuilders have ignored this material as if it did not exist; and this in the face of the fact that for years this metal has been used for purposes where only material of the highest quality is admissible, and that it has given, and is giving, so much satisfaction that those men speak of it the most favorably who have used it the most largely. So many distinguished mechanical engineers have used Bessemer steel, that in speaking of their varied experience, I hardly know where to begin. Sir Joseph Whitworth is making from the Bessemer converter some of the finest material known. By his process of compressing the steel while it is in a liquid condition, he produces a quality far superior to anything which can be made by the ordinary methods of treatment. Sir Joseph writes, "During the last twelve months we have been working night and day, principally on guns, cylinders for hydraulic purposes, cylinder linings, torpedoes, etc.; the melting has been by the Bessemer and crucible processes, and we are just about to use the Siemens-Martin process also. The state of my health has prevented us from commencing new works, but we hope to do so before long." This material is as yet too expensive for use in ordinary work, but Sir Joseph has shown that out of the Bessemer converter can be produced, as I have said, some of the finest material known. Mr. Ramsbottom, when at Crewe, began to use Bessemer steel in the construction of locomotives, and for other purposes, and his able successor, Mr. Webb, has greatly distinguished himself by his care in the manufacture of Bessemer and Siemens steel, and by his skillful and spirited application of the metal to almost every purpose, and particularly in cases where material of the very highest quality is indispensable. No man, I think, has done more than Mr. Webb to improve the quality of mild steel, or so much to extend its general use. Mr. Sharp, of Bolton, was one of the first to produce excellent boiler and ship plates of steel, and to make boilers of steel plates. Mr. Sharp tells me that they have made between nine and ten thousand tons of steel plates at Bolton, three-fourths of which have been used in the construction of boilers. He says that steel plates, with a tensile strength of from 30 to 34 tons, are easily and safely worked by experienced men. They have had steel boilers at work for nine years, and they have given perfect satisfaction, and the repairs are light to those compared with iron boilers. Mr. Adamson, whose talent as a mechanical engineer is well known to us all, informs me that in his steam engines, when the choice of materials is left with him, all the principal parts are made of Bessemer steel, and that the results have been most satisfactory. Mr. Adamson states that he has used various kinds of steel in boiler work, but since the introduction of Bessemer steel plates he has

used no other; of this material he has made between six and seven hundred boilers, mostly for high pressures. He is now making a number of steel shell and fire-box boilers, of 7 ft. diameter, to work 80 lb. and 100 lb. pressure per square inch. Mr. Adamson has used mostly steel plates of Barrow make. He says that they are very uniform in quality, and from all causes he has not had to return or set aside more than one plate in a thousand. He describes his method of working steel plates as follows: "A piece is cut off every plate and tested before the plates are accepted; the edges of the plates, when used for boilers, are all planed, the rivet holes are drilled through both plates together, after the plates are bent and in place; in every case double or chain-riveting is adopted." He goes on to say: "In the application of steel plates for fire-boxes, I have experienced the most satisfactory results; there is no blistering, and the plates show great endurance. When boilers have been allowed to run short of water, the plates have bulged or collapsed, but they were never fractured." In this respect, he thinks that steel plates are superior to any iron ever made. Mr. Adamson, like Mr. Sharp, advocates the use of steel of comparatively low tensile strength, from 30 to 32 tons per square inch. Steel of 38 to 40 tons to the inch was found quite unsuitable for boiler work; it was wanting in ductility, and the use of such a material was quickly abandoned. A great deal has been said and written about the want of uniformity in Bessemer steel, but what could be more satisfactory than Mr. Adamson's experience on this head? Messrs. Galloway, of Manchester, who have a large experience in boiler making, and who are noted for the excellence of their work, inform me that when they commenced using Bessemer steel plates, about 1861, the results were not satisfactory, the plates being too hard, but that of late they have used steel plates extensively, and that the conclusion they have come to is that when the annealing is carefully performed the plates are perfectly trustworthy; in fact, in the testing of boilers they now find quite as little trouble with steel plates as with iron ones, if not less. They state further that careful annealing has a most beneficial effect; and they refer to some experiments made for the Manchester Boiler Insurance Company by Mr. Kircaldy on the strength of riveted joints, which conclusively proved that even in the case of wrought iron plates, which are punched, it is advisable to anneal them. With respect to the employment of steel for bridge work, Mr. Maynard, of the Crumlin Viaduct Works, writes: "With regard to the question of employing steel for railway bridges in this country, I may at once say that, practically speaking, steel is excluded from use by the somewhat arbitrary limitation laid down by the Board of Trade—to 5 tons strain per square inch when used in tension, and 4 tons per square inch in compression—no higher strain being allowed whatever may be the quality of the material, and even if steel is used in place of iron. When a girder bridge is required of a trifle over 400 ft. span for a railway it is found that the weight of the iron, etc., necessary for its construction is alone sufficient, without the rolling load of a train, to strain the iron in the most important parts of the structure to very nearly, if not fully, the limit laid down by the Board of Trade—therefore, we make but little progress in large span bridges in this country. Steel has been employed very successfully in some bridges of large span which I have seen in Holland, and elsewhere, whilst in England we adhere to the old rule-of-thumb practice without much chance of improvement. It is obvious that if a material is used that will bear a high strain, it results in a lighter and stronger structure, and I should be glad to employ steel even in small girders, but for the difficulty of getting the Board of Trade to acknowledge its superiority over iron, and to allow a higher strain to be imposed than is adopted for iron." Having given you the results of the experience of some of our leading mechanical engineers as to the value of mild steel for constructive purposes, I have now the pleasure of laying before you the opinion of a man who has earned a world-wide reputation as a shipbuilder, and whose professional advice is sought by the most powerful Governments in Europe; Mr. Reed, the late Chief Constructor of our navy, writes to me as follows: "In reply to

your favor of the 20th, allow me to say that for more than two years past I have been thoroughly satisfied that the production and methods of working steel had reached a point when that material might be extensively and very advantageously used for shipbuilding purposes. I, therefore, designed some very fast war vessels in steel, and obtained some provisional orders for them, but when I came, two years ago, to the question of building, I could not satisfy myself that the proper supplies could be secured under the same conditions and facilities as iron. This was due, however, entirely to the fact that my orders would not have been sufficient alone to justify any large firm in entering systematically upon the production of steel plates and angles for ship purposes. Great progress has been made in this respect since then, and I am now receiving orders for despatch war vessels to be built of steel —boilers and engines as well as vessels— and I am about to build two at Pembroke, and probably to place others for construction in other establishments. It will, therefore, be a very great advantage if in your address you can stimulate the attention or the profession and the trade to the subject, because I am satisfied, that when once a systematic commencement is made there will, henceforth, be no obstruction to the large development of steel for shipbuilding. I say nothing here about the special arrangements which the use of steel for shipbuilding purposes renders necessary, because, although they are unusual and additional, they are such as present no real difficulties to a careful builder." I would also call attention to the somewhat extensive use of steel in the French navy; and, above all, I would point to what the Germans are doing. In Germany there is no want of confidence in the character of steel. Mr. Krupp, who may be called the father of the steel trade, has evinced a wonderful amount of skill in the production of large masses of steel, and in its application to purposes where its strength and ductility are submitted to the most severe tests. Mr. Longsden informs me that they are making at Essen at the present time 14 inch guns of steel, which weigh, when finished, 57½ tons, carrying a shot 9 cwt. 9¼ English miles, using a charge of 210 lb. of gunpowder. They are about to make steel guns of the following capacities and weights—15¾ in. bore, 80 ft. long, weighing 82 tons, using 300 lb. of powder, with a shell of 1,500 lb. weight; guns of 18 in. bore, 32. ft. 6 in. long, weighing 124 tons, using 440 lb. of powder, with a shell of 2,270 lb. weight. Mr. Longston demurely adds, "It is calculated, for the present, that these guns will be heavy enough to destroy any armor a ship can carry." In gloating over the destructive properties of these weapons, he is leaving out of his calculation, perhaps, the flash-of-lightning ships which Mr. Reed is about to build, and which may, under smart management, be able to get out of the way of such a conspicuous object as a shell weighing over a ton, even when fired with about a quarter of a ton of gunpowder. In alluding to the use of high-class steel for guns, I wish it to be understood that I am not seeking to give any opinion as to the superiority of steel over wrought iron for this special purpose. I merely wish to call attention to the fact that in Germany and, I believe, in most continental countries, as also, I may add, by one at least of our most celebrated gunmakers in England, steel is being used for making guns of the heaviest description; and it is well known that these steel guns have stood the most severe tests at proof, and also when put to their more legitimate use. Speaking of guns gives me the opportunity of calling special attention to the wonderful structures in wrought iron now being built up at Woolwich and Elswick. Forgings are made there which for weight and quality of material were never equalled; and the guns, when finished, even if looked at simply as engineering works, reflect credit not only upon the men who produced them, but upon England as a nation. As we are about to have an inquiry as to the merits of these guns, I sincerely hope that it may turn out, as I daresay it will, that those wonderful weapons have not been constructed to load at the wrong end. You will have observed that in speaking of the present position of mechanical puddling, and of the improvements now in progress, I have preferred, for the most part, to use the language in which the information reached me. It was my intention, for the purpose of this address, to make a

tour through all the works of England and France where puddling machinery is in operation. But when I considered that some machines of great promise are still, strictly speaking, in their experimental phase, I felt that, in the circumstances, even a very careful inspection would not enable me, from my own observation, to arrive at perfectly sound conclusions. I therefore thought it better to invite the gentlemen who are so ably, and I think, successfully, working out the problem of mechanical puddling, to give me information as to the results of their experience, and as to the prospects of their various plans. These gentlemen have with the greatest courtesy, furnished all the information that I sought—information which I am sure will be of the greatest interest to the members of this Institute. I have, like many of you, watched with great interest the advance of mechanical puddling; and from the day, long ago, on which I saw Mr. Toth at work at Stepney until now, I have never for a moment doubted that mechanical puddling would sooner or later be perfected. I think that there is now almost a certainty that this problem, upon which has been expended so much labor and thought, and which has brought to many so much disappointment, will within a short period be fairly solved. I have told you, with the authority of Mr. Bessemer and Mr. Siemens, what improvements they are contemplating in the way of cheapening the production and increasing the make of steel, and I believe that every leading steel maker in England is engaged in devising new modes, or introducing new methods already tried, for increasing and cheapening production and no less for insuring excellence and uniformity of quality. On the question of the applicability of steel to various purposes where it is now used but sparingly or not at all, I have sought the opinions of men whom we all know, most of them being members of this Institute, and all of them holding high rank in their profession; and here again I have preferred, where it was practicable, to give the opinions of the various gentlemen in their own language. Although I have expressed my surprise that steel has not been more largely employed in great engineering works and shipbuilding, I am well aware that there is much to be said in defence of the cautious policy which has guided our engineers and shipbuilders; and I have no desire to cast the slightest reflection on members of either profession for the exercise of a caution which, in all the circumstances, was perhaps natural. If blame there be, manufacturers must take to themselves a fair share of it, as at first, steel was made of unsuitable quality; and when this difficulty was got over, they were somewhat slow to put themselves in a position to supply the trade with steel of suitable sections at a moderate cost. For a long period, as I have said, steel was expensive, and this stood in the way of its general introduction. Makers have ascertained that it possessed great tensile strength as compared with wrought iron, were anxious that it should be used if possible with a comparatively high percentage of carbon, so as to retain this excellent quality; and at first steel with a tensile strength of forty tons per square inch and upwards was made into plates and used for other purposes, for which, as experience has since proved, it was unfitted. There is now, however, amongst the manufacturers a perfect knowledge of what is wanted for various engineering purposes. There is also the power to produce steel of almost any shape or quality at a moderate cost, and it only requires the hearty co-operation of the engineering profession to induce manufacturers everywhere to erect suitable machinery for converting steel into the necessary forms for constructive purposes; and if reasonable encouragement is given in this direction, I have no doubt that healthy competition will soon bring the cost of steel to a point where it will, as a matter of economy, beat certain classes of iron out of the field. I assume, of course, that upon proper proof being given of the superiority of steel, the Board of Trade will modify their rules as to its use. Although the proper business of this Institute is to discuss technical subjects, I will venture to follow the example of my predecessor, and say something of the present position and prospects of our trade. At our last annual meeting, Mr. Bell concluded his excellent address with the following hopeful and spirited remarks: "Whatever difficulty may be-

set us at the present moment, it can only be of a temporary character. Of raw materials we have an abundance; of our skill as manufacturers, whatever may be said to the contrary, we have no reason to be ashamed, and it will be a strange thing if, with these advantages, British energy is unable to hold its own against any people in the world." If England had a fair field she would, beyond doubt, hold her own; and further would continue to be for a long period, as far as iron is concerned, the workshop of the world. But from many important markets in Europe, and from the United States of America, English iron and steel are practically excluded. Heavy import duties are imposed with the avowed purpose of encouraging native manufacture, which means excluding the manufactures of England. The effect of this policy is being severely felt at the present moment, for we have but little demand from Europe, and we seem to have lost our American market entirely.

With our free trade notions we all believe that our neighbors in Europe and our friends in the United States are pursuing a mistaken policy, that they had better confine themselves to the charming Arcadian occupations of growing fine "corn and wine," and let England continue to drudge in the grimy business of iron and steel making. Some sanguine persons believe that some day they will see the error of their ways, and that they will adopt the course above indicated. I confess that on this point I am far from hopeful. If it were merely a trade question we might expect that by and by the example of England would be followed as a matter of self interest, but it is needless to say that in powerful countries the home production of iron and steel means more than giving employment to a portion of the population. In certain contingencies it renders a nation independent of foreign supplies at times when such dependence would cripple the most powerful nation in the world. There is, moreover, another reason why we can hardly expect to see, within a reasonable time, the principles of free trade introduced. Governments have encouraged the growth of gigantic industries devoted to the manufacture of iron and steel; and any one who has had the privilege of seeing the vast works of Creusot and Essen, would, I think, admit that no Government, however wise or strong, would lightly venture on a policy which would interfere with the prosperity of such establishments. We must, I think, frankly accept the position in which we are placed, and prepare to seek new markets for our produce in countries which, even if they have the will, have not yet the power to impose restrictions on our trade.

STRAINS IN CONTINUOUS GIRDERS.

By MANSFIELD MERRIMAN, C. E., New Haven, Conn.

Written for Van Nostrand's Magazine.

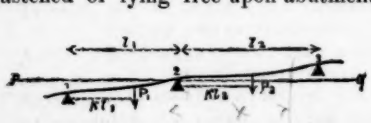
In designing a bridge truss continuous over many supports the engineer is often at a loss for want of English treatises on that subject. Such as he is able to consult, he is generally apt to find unsatisfactory on account of their incompleteness, or the tediousness of the approximate methods used. Although the later works of German and French writers contain the complete and satisfactory theory of the continuous girder under every variety of loading, the results have not yet been made available to the practical engineer. In fact the formulae for the maximum bending moments in every section due to a combination of the dead and live loads are complex, and not easy of application. Such formula are, however, entirely unnecessary for the calculation of strains in any truss. They do not shorten the work, but rather impede it, particularly in the hands of those to whom algebraic expressions are not thoroughly familiar.

The maximum stresses in a continuous truss may be easily and completely determined, *when the moments and vertical forces at every support due to any position of a concentrated load can be found.* In a simple girder, we know at once from

the law of the lever, the reactions at the abutments; but in a continuous girder they are not so easily obtained. In fact it is not generally known among American engineers that the shearing forces, due to a single concentrated weight on a girder continuous over any number of supports, can be computed. Although the extension of Clapeyron's theorem to concentrated loads was published ten years ago, and has since been prominent in German and French engineering works, it has not yet gained the attention of the English and American public. For example, in a recent work on the Analysis of Bridge Trusses, by the graphical method it is stated that "a complete solution for the bending moment and shearing force at every section, under moving partial and irregular loads, is well nigh impossible, on account of the complexity of the formula, so far as any practical application of them by the engineer is concerned," and the same author* frequently asserts that Clapeyron's theorem can only be used for uniformly distributed loads.

I propose to give in this article a demonstration of the Theorem of Three Moments for the case of girders of constant cross section, subject to loads either regular or irregular, uniform or concentrated, and to show how the reactions due to such loads can be found. Then by practical examples I shall show how the maximum moments and shearing forces at every section can be computed, without the aid of any formulae, except those for finding the moments and vertical forces at the supports, by a method as simple and as easily applied by the engineer as those in common use for the case of a truss of one span.

Let l_1 and l_2 be two spans of a girder continuous over any number of supports, the supports being either on the same or different levels, and the two ends either fastened or lying free upon abutments.



The moment at a support will be designated by the letter M with an index corresponding to that of the support, thus M_2 and M_3 are the moments at the supports 2 and 3. The reaction will be represented by R in the same way. In the span l_1 let there be a single concentrated load, P_1 at a distance kl_1 from the left hand support, also in the span l_2, a load P_2 at a distance kl_2 from 2; k being any fraction and not necessarily the same in the two cases. Let us take the support 2 as an origin; and designate by **m** the moment at any point in the span l_2. Now if we consider any section between the load P_2 and the support 3, we know the sum of the moments of all the exterior forces acting upon the beam upon the left of this point must be equal and opposed to the moment of the molecular forces in the section. Now all the exterior forces to the left of the point 2 may be conceived as acting at 2 in the unknown moment M_2 and an unknown vertical shearing force S_2. Denoting the distance of the section from the origin by x; we have the equation of moments with reference to this section:

$$(1)\quad M_2 - S_2 x + P_2 (x - k l_2) - \mathbf{m} = o$$

Making in this $x = l_2$, **m** becomes M_3, and we have

$$(2)\quad S_2 = \frac{M_2 - M_3}{l_2} + P_2 (1 - k)$$

Considering now a section in the span l_2 between P_1 and the support 1, we have all the exterior forces to the right of 2 represented by the moment M_2 and an unknown vertical force S'_2, and the equation of moments for that section is analogous to (1); making $x = l_1$, we deduce the value

$$(3)\quad S'_2 = \frac{M_2 - M_1}{l_1} + P_1 k$$

Now the reaction at the point 2 is the sum of these two partial reactions, hence adding (2) and (3) we have

$$(4) R_2 = \frac{M_2 - M_1}{l_1} + \frac{M_2 - M_3}{l_2} + P_1 k + P_2 (1 - k)$$

Hence the shearing force and the reaction at any support may be obtained when the moments at that support and at the preceding and following supports are known.

These are found by the wonderful

* C. E. Greene, *Graphical Method for the Analysis of Bridge Trusses.* D. Van Nostrand, New York. 1875.

Theorem of Three Moments, of which an abridged demonstration will now be given. Through the origin pass a horizontal line $p\,q$, and let the height of any support *above* that line be denoted by h. Let the tangent of the angle which the elastic curve at any point makes with this horizontal be denoted by t. The well known equation of the elastic line is

$$(5)\quad \frac{d^2y}{dx^2}=\frac{\mathbf{m}}{E\,I}$$

Where E is the modulus of elasticity, I the moment of inertia of the girder, and **m** the moment at the point whose coordinates are x and y. Inserting for **m** its value from (1) we have

$$(6)\quad \frac{d^2y}{dx^2}=\frac{M_2-S_2\,x+P_2\,(x-k\,l_2)}{E\,I}$$

Integrating this once, the constant of integration is t_2 the tangent at 2, and

$$(7)\quad \frac{dy}{dx}=t_2+\frac{2\,M_2\,x-S_2\,x^2+P_2\,(x-kl_2)^2}{2\,E\,I}$$

Integrating again the constant is zero, and

$$(8)\quad y=t_2\,x+\frac{3\,M_2\,x^2-S_2\,x^3+P_2\,(x-k\,l_2)^3}{6\,E\,I}$$

Making in (8) $x=l_2$ we have $y=h_2$, and substituting for S_2 its value from (2) we have for t_2 the expression

$$(9)\quad t_2=\frac{h_2}{l_2}-\frac{1}{6\,E\,I}\left(\begin{matrix}2M_2\,l_2+M_1l_2-P_2\,l_2^2\\ [2\,k-3\,k^2+k^3]\end{matrix}\right)$$

If now we make in (7) $x=l_2$, $\frac{dy}{dx}$ becomes t_2, and by substituting in (7) the value of t_2 from (9), we get

$$(10)\quad t_2=\frac{h_2}{l_2}+\frac{1}{6\,E\,I}\left(\begin{matrix}M_2\,l_2+2\,M_1\,l_2-P_2\,l_2^2\\ [k-k^2]\end{matrix}\right)$$

Considering now the origin at the support 1, we may derive a value for t_2 by simply diminishing each of the indices in (10) by unity, therefore

$$(11)\quad t_2=\frac{h_1}{l_1}+\frac{1}{6\,E\,I}\left(\begin{matrix}M_1l_1+2\,M_2l_1-P\,l_1^2\\ [k-k_1]\end{matrix}\right)$$

Comparing (9) and (11) the tangents will eliminate, and we have

$$(12)\quad M_1\,l_1+2\,M_2\,(l_1+l_2)+M_2\,l_2=6\,E\,I\left(\frac{h_1}{l_1}+\frac{h_2}{l_2}\right)+P_1l_1^2\,(k-k^2)+P_2\,l_2^2\,(2\,k-3\,k^2+k^3)$$

Which is the most general form of the theorem of three moments for a girder of constant cross section. When the origin is at 1 as in (11) the line $p\,q$ is supposed to pass through that support, and since (12) refers to the support 2, h_2 should be replaced by $-h_1$, as is there done. If the supports are all upon the same level $h=o$, and the second member of the equation contains only loads involving P. If there be several loads, it is only necessary to prefix the sign of summation Σ to the two terms involving P. For the case of a uniform load w_1 and w_2 per unit of length, we have only to put $\Sigma\,P_1=w_1\,d\ (k\,l_1)$ and $\Sigma\,P_2=w_2\,d\ (k\,l_2)$, and to integrate between the required limits; thus, if the load cover both spans entirely, the integral is taken between the limits o and l, and we have (if the supports are on the same level)

$$(12)^*\quad M_1\,l_1+2\,M_2\,(l_1+l_2)+M_2\,l_2=\tfrac{1}{4}\,w_1\,l_1^3+\tfrac{1}{4}\,w_2\,l_2^3$$

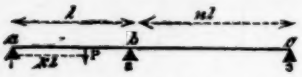
And the reaction for the corresponding support becomes, from (4)

$$(13)\quad R_2=\frac{M_2-M_1}{l_1}+\frac{M_2-M_3}{l_2}+\tfrac{1}{2}\,w_1\,l_1+\tfrac{1}{2}\,w_2\,l_2$$

When the supports are on the same level, and the ends of the girders lie upon abutments, formula (4) and (12) are of easy application. The moments at the ends are then zero, and for each intermediate support may be written an equation of the form of (12) by which the moments can be found, since the number of equations is the same as that of the unknown qualities. Then by substitution in expressions of the form of (4) the reactions become known.

If we have two spans $a\,b=l$, $b\,c=n\,l$, there is only one equation of moments. Let us apply this to a single concentrated weight on the span $a\,b$. Referring to (12), we have then

* This is the form as first deduced by Clapeyron, *Comptes Rendus*, 1857. The form as given in (12) is due to Bresse, *La Mécanique Appliquée*, 1865. A more general extension to the case of variable moment of inertia is given by Weyrauch, *Theorie der Continuirlichen Träger*, 1873.



(14) $2M_2(l+nl)=Pl^2(k-k^3)$ or

$$M_2=\frac{Pl}{2+2n}(k-k^3)$$

Then from (4) we have

$$R_1=-\frac{M_2}{l}+P(1-k)=\frac{P}{2+2n}\left(2+2n-(3+2n)k+k^3\right)$$

(15) $$R_2=\frac{M_2}{l}+\frac{M_2}{nl}+Pk=\frac{P}{2n}\left([2n+1]k-k^3\right)$$

$$R_3=-\frac{M_2}{nl}=-\frac{P}{2n+2n^2}\left(k-k^3\right)$$

Now for our practical illustration, let $ab=80$ ft. and $bc=100$ ft, hence we have $n=1.25$, and the formula become

$$R_1=P(1-1.222k+0.222k^3)$$

(16) $$R_2=P(1.4k-0.4k^3)$$

$$R_3=-P(0.177k-0.177k^3)$$

For a load P′ on the span bc, we may call $bc=l$ and $ab=nl$, and estimate the abscissa of the load by kl measured from the support c. Then we have $n=0.8$, and from (15) we have

(17) $R_1=-P'(0.3742k-0.3742k^3)$
etc.

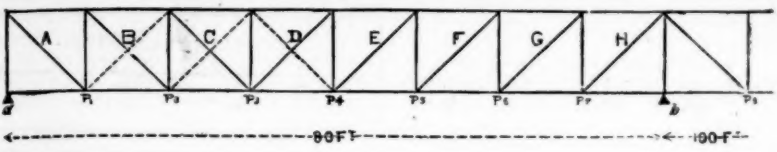
Suppose now the span ab to be divided into eight and bc into ten panels. Let the dead load of the truss be 2.5 tons per panel, and the live load 5 tons. To find all the strains in the span bc it is only necessary to compute the reactions at a due to a load $P=P'=5$ tons for every panel point. Putting then, in the first of formula (16), k equal successively to $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, etc., we find the values for all loads on the span ab; then in (17) making $k=\frac{1}{10}$, $\frac{2}{10}$, etc., we get the values for loads on bc. There are given in the annexed table, P_1 to P_7 inclusive, being the loads on the span ab, as shown in the diagram given below, while P_8 to P_{16} are

REACTIONS AT a, P=4 tons.

Load.	R_1	Load.	R_1
P_1	+4.24	P_9	−0.29
P_2	+3.49	P_{9}	−0.54
P_3	+2.77	P_{10}	−0.65
P_4	+2.08	P_{11}	−0.66
P_5	+1.45	P_{12}	−0.65
P_6	+0 88	P_{13}	−0.58
P_7	+0.39	P_{14}	−0.47
		P_{15}	−0.33
		P_{16}	−0.17
P_1-P_7	+15.30	P_8-P_{16}	−4.34

the loads on the span bc, P_8 being the one nearest to the pier b, and the others following in the order of their indices. The computation of reactions is always very simple when the formula are once put into the shape of (16) and (17), and may be done by an office-boy acquainted with only the first elements of algebra. However great the number of spans, there will never be more than three terms involving k, the numerical coefficients of which may be deduced for every case by a process similar to that illustrated above.

Let us take the Murphy-Whipple pattern as the style of our practical example; the vertical posts are to be struts, and the diagonals ties. The load is to be applied to the lower chord. We then know that the ties near the end a, must slope upward toward the abutment, and that those near b must slope upward toward the pier. These two systems of ties must meet at the panel point where the shearing force due to a uniform load changes from positive to negative. In a simple girder this point is at the middle of the truss. From our table of reactions, we see that a reaction at a for a uniform load of 5 tons per panel is $15.30-4.34=10.96$ tons, and this is the positive shearing force in the panel A, for the panel B we have $10.96-5=5.96$ tons, for C $5.96-5=0.96$, and for D $0.96-5=-4.04$ tons. Hence the two systems of ties meet at the panel point between C and D. From the table of reactions we may now tabulate the shearing forces due to each weight. Taking for instance the load P_9, its reaction is +3.49 tons; this acts as a positive shear in the panels A and B; for all the other



SHEARING FORCES.

		A	B	C	D	E	F	G	H
1	P_1	+4.24	−0.76	−0.76	−0.76	−0.76	−0.76	−0.76	−0.76
	P_2	+3 49	+3.49	−1.51	−1.51	−1.51	−1.51	−1.51	−1.51
	P_3	+2.77	+2.77	+2.77	−2.23	−2.23	−2.23	−2.23	−2.23
	P_4	+2.08	+2.08	+2.08	+2.08	−2.92	−2.92	−2.92	−2.92
	P_5	+1.45	+1.45	+1.45	+1.45	+1.45	−3.55	−3.55	−3.55
	P_6	+0.88	+0.88	+0.88	+0.88	+0.88	+0.88	−4.12	−4.12
	P_7	+0.39	+0.39	+0.39	+0.39	+0.39	+0.39	+0.39	−4.61
	P_8—P_{16}	+4.34	−4.34	−4.34	−4.34	−4.34	−4.34	−4.34	−4.34
2	Live Load +	+15.30	+11 06	+7.57	+4.80	+2.72	+1.27	+0.39	
3	Load —	−4.34	−5 10	−6.61	−8.84	−11.76	−15.31	−19.43	−24.04
4	Sums	+10.96	+5.96	+0.96	−4.04	−9.04	−14.04	−19.04	−24.04
5	Dead Load	+5.48	+2.98	+0.48	−2.02	−4 52	−7.02	−9.52	−12.02
6	+ Maxima	+20.78	+14.04	+8.05	+2.78				
7	— Maxima		−2.12	−6.13	−10.86	−16.28	−22.33	−28.95	−36.06

panels we have $+3.49-5.=-1.51$ tons. In this way all the shearing forces are readily tabulated, and the position of the load required to produce the maxima is seen by inspection. For the panel D we see that P_1 to P_7 inclusive give positive shears while all the other loads produce negative. The maximum positive shear will then obtain when the rolling load extends from D to the pier *b*, and the greatest negative shear when the span *b c* and the segment *a D* is covered. Adding then the positive values in the vertical columns we get the horizontal column 2, which gives the maximum positive shearing forces due to the rolling load of 5 tons per panel. Adding the negative values we get in 3, the negative maxima. Taking the sums of the quantities in 2 and 3, we have in 4 the shearing forces due to a dead load of 5 tons per panel. Since the dead load is 2.5 tons per panel, we take one-half of these quantities, which gives us in 5 the shears due to the actual dead load. Then the positive maxima are the sums of the values due to the dead load and the maximum values for the live, that is the sums of the numbers in 2 and 5 give the positive maximum shears which are placed in column 6. Similarly the negative maxima in 7 are obtained by the addition of the values in 3 and 5. For the panels B, C and D, we notice that either a plus or minus shear may occur, which necessitates the introduction of counter ties in those panels, and which are shown on the diagram by dotted lines. The shearing forces are the strains upon the posts, and multiplied by the secant of the angle which the diagonals make with a vertical, they give the strains upon the ties.

We may now pass to the calculation of the moments. Let those be taken as positive which tend to produce tension in the upper chord, while those causing compression will be negative. Suppose only one load upon the truss, say P_5, and consider its action upon the upper chord in the panel G. If the chord be cut at this panel, revolution will begin at the

intersection of the diagonal and lower chord, the point marked by P_6 in the figure. This then is the centre of moments. The reaction of P_2 is 3.49, and its lever arm with reference to the centre of moments is the length of six panels or 60 feet. The moment of the reaction is then -3.49×60, the negative sign being used because it tends to turn the system in a right-handed direction about the centre of moments, and hence to cause compression in the upper chord. The lever arm of P_2, with reference to the same point, is the length of four panels or 40 feet, hence its moment is 5×40, with a positive sign since it acts downward. Then the total moment for the upper chord in the panel G is

$$5 \times 40 - 3.49 \times 60 = -9.4 \text{ ft. tons.}$$

In this way the moments due to every concentrated load are readily obtained and tabulated. Since all of the loads in the span *b c* produce a negative reaction at *a*, the moments due to their action is simply obtained by the product of the reaction -4.34 into the various lever arms, 10, 20, etc.

An inspection of this table shows that the maximum negative moment for all the upper chords, except that of the panel H, is produced when the span *a b* is fully loaded and *b c* unloaded. For H the negative maximum occurs when only the loads P_8, P_9 and P_{10} are present, and the positive maximum when these three are absent and the remainder of the girder loaded. Adding the positive and negative values we get in the horizontal columns 2 and 3, the maxima due to the live load. Taking one-half of the algebraic sum of the numbers in 2 and 3, we get in 4 the moments due to the dead load of 2.5 tons per panel. Then

MOMENTS FOR UPPER CHORD.

			A	B	C	D	E	F	G	H
1		P_1	−42.4	−34.8	−27.2	−27.2	−19.6	−12.0	−4.4	+3.2
		P_2	−34.9	−69.8	−54.7	−54.7	−39.5	−24.5	−9.4	+5.7
		P_3	−27.7	−55.4	−83.1	−83.1	−60.8	−38.5	−16.2	+6.1
		P_4	−20.8	−41.6	−62.4	−62.4	−83.2	−54.0	−24.8	+4.4
		P_5	−14.5	−29.0	−43.5	−43.5	−58.0	−72.5	−37.0	−1.5
		P_6	−8.8	−17.6	−26.4	−26.4	−35.2	−44.0	−52.8	−11.6
		P_7	−3.9	−7.8	−11.7	−11.7	−15.6	−19.5	−23.4	−27.3
		P_8—P_{16}	+43.4	+86.8	+130.2	+130.2	+173.6	+217.0	+260.4	+303.8
2	Live Load	−	−153.0	−256.0	−309.0	−309.0	−312.0	−265 0	−168.0	−40.4
3		+	+43 4	+86.8	+130.2	+130.2	+173.6	+217.0	+260.4	+323.2
4		Sums	−109.6	−169.2	−178.8	−178.8	−138.4	−48.0	+92.4	+282.8
5		Dead Load	−54.8	−84.6	−89.4	−89.4	−69.2	−24.0	+46.2	+141.4
6		− Maxima	−207.8	−340.6	−398.4	−398 4	−381.2	−289.0	−121.8	
7		+ Maxima		+2.2	+40.8	+40.8	+104.4	+193.0	+306.6	+464.6

combining 5 with 2 and 3 we get in 6 and 7, the negative and positive maximum moments due to the combination of the dead and live loads.

For the lower chord the centres of moments will be at the intersection of the ties with the upper flange. Hence we have the moment for A equal to zero, and the moments for B, C, D, E, F, etc., will be the same with a reversed sign as those for the upper chord in A, B, E, F, G, etc. Only the moment for the lower chord in H remains to be found. This may be computed in the same way as those above. Its value is 523.2 ft. tons.

Let the height of the truss be 10 feet. Then from the table of shears the maximum stresses for the diagonals are found by multiplying by the secant of 45° or $\sqrt{2}$.

From the table of moments the chord strains result by dividing by the depth of the truss. Hence the following table of

MAXIMUM STRAINS.

	A	B	C	D	E	F	G	H
Left Hand Post.....	−20.8	−14.0	−8.1	−8.9	−10.9	−16.3	−22.3	−29.0
Tie.....	+29.7	+19.6	+11.3	+15.3	+22.8	+31.3	+40.6	+50.5
Counter tie.....		+3.0	+8.6	+3.9				
Upper chord.....	−20.8	−34.1 +0.2	−39.8 +4.1	−39.8 +4.1	−38.1 +10.4	−28.9 +19.3	−12.2 +30.7	+46.5
Lower chord.....	0.0	+20.8	+34.1 −0.2	+38.1 −10.4	+28.9 −19.3	+12.2 −30.7	−46.5	−52.3

Where + denotes tension and − compression. To complete the calculation for the span bc it is only necessary to find the strain in the post over b. This is evidently a maximum when the whole girder is covered with both dead and live loads, and is equal to the reaction of the pier, or to the sum of the shearing forces in the two adjacent panels. From (16) and (17) we find the reaction at b for that case to be 77.5 tons, which is the value of the maximum compression in the post.

To recapitulate then the processes for finding the maximum strains in the end spans of any continuous truss; compute the reactions at the free end by the formula (4) and (12) for a single load at each panel point. Then tabulate the shearing forces in every panel due to each weight and deduce the maximum shears by a combination of the dead and live load, as fully explained above. Then from the reactions compute the moments due to single loads. From the shears the strains in web are found, while the moments give the stresses for the chords.

The truss which has been computed above is the simplest form of a continuous girder. There being no moment at the abutments the computations of the ends reactions is alone sufficient to determine the strains; but as we see from (1) the moment at any section depends upon the moment at the support, and when these exist they must be taken into account. If it be required to compute a truss of six spans, we need then to find the moment and shear at each support for every position of a single weight. These can be determined by the Theorem of Three Moments for every case, but when the number of spans becomes great the preliminary calculation of these quantities is tedious. A general solution of the equations of moments can, however, be made, and put into shape for direct use.

I propose now to present without demonstration a few simple expressions that contain the whole theory of continuous girders over level supports. A proof for analogous expressions as applied to girders of equal span may be seen by the reader in the "Journal of the Franklin Institute," for April, 1875. These formula will give the moments at every section due to a single load P, and the shearing force at the right hand side of every support. They will be found by the engineer to be easy of application, and in connection with the method of tabulation given above will completely solve every girder.

Let V s= number of spans, l_r = length of the span containing the load P, l_1 l_2 l_3, etc., the length of the spans counting from the left hand end, and l_s, l_{s-1}, etc., beginning at the right hand end. In the same way let the supports be numbered 1, 2, 3, etc., then r will denote the support at the left of the loaded span. A single load will be called P, and its distance from the r^{th} support will be a, or $k\,l_r$ where k denotes any fraction.

The moment at any support will be called M_n, and the shearing force at a point infinitely near to the support will be designated by S_n.

Then the moments and shears due to a single load P will be given by the following formulae :

(I.) The moments at the supports

when $n<r+1$,

$$M_n = c_n \frac{A\, d_{s-r+2} + B\, d_{s-r+1}}{l_2\, d_{s-1} + 2\,(l_1+l_2)\, d_s},$$

and when $n>r$,

$$M_n = d_{s-n+2} \frac{A\, c_r + B\, c_{r+1}}{l_{s-1} c_{s-1} + 2\,(l_{s-1}+l_s)\, c_s}$$

(II.) The shears at the supports

at the r^{th} $\quad S_r = \frac{M_r - M_{r+1}}{l_r} + P\,(1-k)$

at any other $S_n = \frac{M_n - M_{n+1}}{l_n}$

(III.) The moments at any section, whose distance from the left hand support is x.

Between P and the right hand support
$$m = M_r - S_r\, x + P\,(x-a)$$

At any other section $\quad m = M_n - S_n\, x$

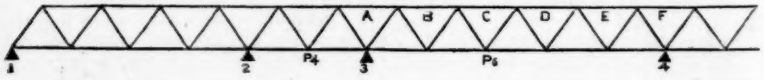
The constants c_1 c_2 c_n, etc., and d_1 d_2 d_s, etc., depend only on the lengths of the various spans; A and B depend only on the load P and its position in the r^{th} span; the values of these constants are :

$$c_1 = 0$$
$$c_2 = 1$$
$$c_3 = -\,2\,\frac{l_2+l_3}{l_2}$$
$$c_4 = \frac{4\,(l_1+l_2)\,(l_2+l_3) - l_2^2}{l_2\, l_3}$$
$$c_5 = -2\,c_4\,\frac{l_3+l_4}{l_4} - c_3\,\frac{l_3}{l_4}$$
etc. $\qquad$ etc.

$$d_1 = 0$$
$$d_2 = 1$$
$$d_3 = -\,2\,\frac{l_s+l_{s-1}}{l_{s-1}}$$
$$d_4 = \frac{4\,(l_s+l_{s-1})\,(l_{s-1}+l_{s-2}) - l_{s-1}^2}{l_{s-1}\, l_{s-2}}$$
$$d_5 = -2\,d_4\,\frac{l_{s-2}+l_{s-3}}{l_{s-3}} - d_3\,\frac{l_{s-2}}{l_{s-3}}$$
etc. $\qquad$ etc.

$$A = P\,l_r^2\,(2k - 3k^2 + k^3) \qquad B = P\,l_r^2\,(k - k^3)$$
$$k = \frac{a}{l_r}$$

To apply these to any case we first insert the lengths of the spans in the series c and d. For six spans we need only to use them as far as c_6 and d_6. Then take a load on the first span, or $r=1$, and making n equal to 2, 3, 4, etc., find from (I.) the moments at every support. For example, let us take a girder of six spans, one-half of which is represented in the sketch, and the other half of which is symmetrical to this



or $l_1=l_6=80'$ $l_2=l_5=40'$ $l_3=l_4=100'$.

Inserting these values in the series c and d we get

$$c_1 = \quad d_1 = \quad 0$$
$$c_2 = \quad d_2 = \quad 1$$
$$c_3 = \quad d_3 = -6$$
$$c_4 = \quad d_4 = \quad 16.4$$
$$c_5 = \quad d_5 = -59.6$$
$$c_6 = \quad d_6 = \quad 222.$$

Now to compute the span 3—4, we need to find the moments at 3 and 4 for a load at every panel point. This is easily done from formula (I). For example, take the load P_4 in the second span, here $r=2$, and $n=2$, hence we get

$M_3 = 1.873\ P_4\,(4k + 3k^2 - 7k^3)$, or since $k=\frac{1}{2}$, $M_3 = 3.513\ P_4$

and $M_4 = -0.525\ P_4\,(4k + 3k^2 - 7k^3)$ or $M_4 = -0.985\ P_4$

Then the shearing force due to P_4 is by (II)

$$S_3 = \frac{M_3 - M_4}{l_3} = 0.045\ P$$

From the moment M, and the shearing force S, the moment for any section can be found. Then by a tabulation of the moment due to every load the maxima are easily obtained as shown above.

If the dead load be 10 tons per panel and the live 20 tons; the height of the truss 10 feet, the maximum strains in the upper chord are:

A	B	C	D	E	F
+184. tons.	+52.4	+16.9 −26.4	+31.1 −29.0	+96.3	+220.6

By comparing these with the strains in a simple girder of the same span, height and load, the reader will observe that the continuous girder effects a saving of over twenty per cent. in material.

BUILDING MATERIALS AS REPRESENTED AT VIENNA.

From "The Builder."

Few things are likely to prove more instructive to the architect, or to the builder, than a comparative view of the character of building materials, as now employed, not only in this country, but on the Continent. For such a glance the reports and technical papers relating to the Vienna Exhibition furnish valuable information. The collections of building materials there exhibited were of sufficient importance to prove of great interest to the engineer, the architect, and the builder, although it was difficult to obtain a clear and satisfactory view of the whole of them; as they were divided into two groups, and scattered through the various galleries, the pavilions, and the grounds.

The United States sent specimens of a fine red sandstone, known as Connecticut freestone. This stone is much employed in New York; as its appearance is much in its favor, and it is easily worked. The price is about half that of granite. A yellow sandstone, easy to cut and to carve, was exhibited from Cleveland, Ohio; and specimens of granite from Vermont; and of red, white, black, and red-grained marble; completed the list of the American exhibits of this class.

From England, the specimens forwarded were principally those of artificial, rather than of natural, building materials. Of the latter, the samples of slate were most worthy of notice, and far excelled any from other countries. A slab from the Welsh Slate Company was 9 feet 10 inches long, and 6 feet 3 inches wide, weighing 32 cwt. At the other extremity of the scale of size, plates of only four hundredths of an inch in thickness, were also shown. Fine building materials, including sandstones, limestones and clay, were contributed from Canterbury, in New Zealand; and Queensland sent specimens of marble and of clay.

Amongst artificial building materials, the first place seems to have been accorded to the Portland cement, which is manufactured on the banks of the Thames and of the Medway. The materials employed are chalk and clay, and the works are, for the most part, situated on the chalk, the clay being brought to the manufactory from a distance. In the cement works on the banks of the Thames, the white, or upper chalk, in a portion of which flint bands and modules occur, is used. On the Medway, the gray, or lower chalk, in which much siliceous matter is distributed through the mass, so that it serves for a very fine material for interior work, is employed. The clay is the common dark blue clay, which is obtained in any requisite quantity along the shores of the confluent rivers. It consists of 68 per cent. of silica, 12 per cent. of alumina, 15 per cent. oxide of iron, with a small quan-

tity of alkaline matter, and a trace of lime.

Cement is manufactured either by a wet or a dry process. In the former, some four parts of gray chalk, or three of white, mixed with one of clay, are ground with water in a mill, until they attain the consistency of cream. This is allowed to flow from the mill into settling-tanks; whence it is removed, when dry, to hot plates. It is then burnt in a kiln, and finally reduced to powder in a grinding-mill.

The dry process is much used on the the Continent. The chalk and clay are first dried, then broken up, and then ground between vertical stones. The powder is placed in a pug-mill, and mixed with water containing freshly-burned chalk, with the addition of a little calcined soda, in the proportion of three measures of powder to one of water. The semi-fluid thus produced is cut into bricks as it issues from the pug-mill, in a continuous stream 10 inches wide and 5 inches deep. These blocks are removed on boards, dried, baked in a kiln, and finally ground to powder. It will be seen that although the latter is called a dry, and the former a wet, process, the chief difference lies in the amount of water which, in one or the other series of operations, is first mixed with calcareous, agrillaceous, and siliceous matter, and afterwards driven off by heat.

The selenitic mortar invented by Lieutenant-General Scott, R.E., is another artificial building material, described in the same reports. The process of production consists in mixing, with the water used in the preparation of the mortar, a small quantity of sulphate of lime, in the form of either plaster of Paris, gypsum, or green vitriol. The water and sulphate are first mixed in a pan, the lime is then added, and the mixture is worked into a creamy paste. After grinding for three or four minutes, the sand, burnt clay, or other ingredient used in the composition is added, and the whole is ground for ten minutes more. It is claimed that by this invention ordinary lime can be at once converted into an excellent cement-like mortar, which sets rapidly and well, and can be used for masonry, concrete, or plasterers' work.

General Scott applies a modification of the same process to the manufacture of bricks. He mixes one part with lime, eight or ten parts sand or burnt clay, and produces bricks which are said to be ready for use in about ten days after pressing, without being burned. The addition of sulphur to the lime used is also said to have the effect of preventing the swelling of the brick, from the water absorbed by the lime in process of stacking.

An invention of posterior date to that of the selenitic mortar, is General Scott's sewage cement. The principle of this manufacture is the precipitation of the solid ingredients of sewage, and the removal of their organic constituents by burning. In the mineral deposit which is left, substances are present which are analogous to the components of the limestones that are used in the manufacture of hydraulic cement. The residue after calcination bears the nearest affinity to Portland cement, which is produced by calcining three parts of chalk with one of clay. But the state of comminution in which the material existed in the sewage is such as to make the mixture more homogeneous than in the case of the Portland process. It should be remarked that the calcined residuum is said to be valuable as manure, not only from the lime which it contains, which would be of service on arenaceous or agrillaceous soils, but also from the presence of from 1 to 2 per cent. of phosphoric acid. It is on this element that the utility of sewege as manure principally depends. The organic matter contained in sewage is not a material which the roots of plants can assimilate. It is the chief source of danger in case of neglect.

In pottery, the exhibits do not appear to have come up to the number or quality of those which we have hitherto described as displayed at South Kensington. The encaustic tiles of Messrs. Minton, made from Kaolin and various colored clays, dried and pressed, the glaze being obtained from felspar, are well known. Mr. Robert Minton Taylor exhibited a novelty, under the name of mosaic tiles. They consist of small cubes of about $\frac{1}{3}$ inch on the side, closely compressed in a powerful press, and afterwards burnt. A third specialty consisted in the majoli-

ca tiles, made of white clay, with drawings either painted or printed, partly under and partly on the glazing. While small in number, these exhibits were exquisite in quality.

The natural building materials supplied from France contained a large collection of slates from the Ardennes. Roofing slates, in thickness of from $\frac{1}{8}$ inch to $\frac{3}{16}$ inch, ranged in color from a pale red to a clear pale blue. Other specimens exhibited enamelled paintings on a highly polished dark ground, of the natural color. A beautiful fine-grained white sandstone is supplied from the Drôn. French marbles are numerous and excellent. The fine Griotte d'Italie and Griotte Compan marbles are dark red, with spots of a dark color, and white veins. They come from the quarries of Félines-Hautpoul (Hérault). The Languedoc is another marble from the same quarries, with white spots, and dark in veins. A light red marble, with spots of a darker red, comes from the Hautes Pyrénées. The Breche Impériale is a light-colored marble, clouded with red and grey, spotted with red and yellow, and darkly veined. It is quarried near the mouth of the Rhone. The Grand Antique, from La Rochelle, has an almost uniform red hue. A dark green marble, veined here and there by both lighter and darker streaks, which takes a beautiful polish, comes from the Basses Alpes. A fine white statuary marble, not unfit to compete with those of Italy, is quarried in the Haute-Garonne, and known as the Blanc de Béat. The transparent onyx marbles, with which we have had the opportunity of making ourselves acquainted at South Kensington, are not found in France, but are imported from Mexico. A similar, but somewhat inferior quality, is found in Algiers.

The art tiles manufactured by M. Deck, and those of M. Collinet, both of Paris, are excellent in design and in execution, although their price is too high to allow of a very general introduction of this decorative material. The bright colors employed by M. Deck are heightened by a peculiar glaze; most of the designs are Persian. M. Collinet has succeeded in the production of large tiles—some as much as a metre square. A special process, called *émail-cloisonné*, is applied to these large *panneaux*. A white glaze is first placed on the tile. On this the design is painted in black. During burning, the enamel contracts, which gives a relief to the drawing, the colors of which are heightened. A panel of 3 feet 3 inches square, thus finished, costs from £14 to £18.

In coarser pottery, and the manufacture of bricks, France was not a formidable competitor with ourselves. Some curved, wedge-shaped, and dove-tailed bricks, constructed for different special purposes, were sent from Mezieres.

The Boulogne cement is a remarkable manufacture, well known in France. Its ordinary color is yellow, but it is made into blocks of a pale blue tint. Plates of two metres long by one wide, and not more than $\frac{1}{4}$ inch in thickness, were exhibited with perfect surfaces. Thirty bricks, placed one on another in a pile, united by this cement, were suspended from a beam. The hydraulic lime of Lapage-du-Thiel is produced in large quantities in the Ardeches. As much as 18,000 cubic per diem is turned out from thirty-four furnaces, which use from 80 to 100 tons of coal. The slacking of the burnt limestone, which is carried on in sheds, is aided by jets of steam. Ten days are required to pulverize the mass, which is then passed through bolting-machines. The residuum is ground and made into cement. This lime is used to a large extent for harbor work, in the form of *béton*, or concrete; blocks of which were exhibited that had been under water for twenty-five years, without showing any signs of change. The cement made from the refuse of the bolting-machines, mixed in equal proportions with sand, make good water-pipes, with smooth and even surfaces. A proportion of three-parts sharp new sand to one of the cement makes a serviceable brick. Colored tiles of various hues, paving, pedestals, and other architectural requisites, are made from the same material.

The "carton pierre" of MM. Hardouin and Lefevre, of Paris, is largely employed for architectural decoration in that city. Its superiority to plaster is so great that it would be interesting to know why the attempt made, some time since, to introduce this material into London has not been attended by more signal success.

The native marbles of Belgium may compete with those of France. Some very beautiful kinds are found in the province of Namur. The *Grive Gérard* is of a light grey color, with small black spots distributed regularly over the whole surface. The *Lilas* is of a brighter grey, with white and also very dark spots. The *Florence* is of a reddish grey color, with brown spots; the *Coquille* is bluish black, with light spots, in the form of mussel-shells; the *Marbre Bois* shows a fibrous pattern on a back ground. A pure black marble, from Mazy-Galzines, is remarkable for the facility with which it can be worked, a quality very rare in black marbles. It is worth as much as 15s. per cubic foot. Inferior marble suitable for pavements, can be obtained for a part of this price.

Roofing slates from Luxembourg are divided into fifteen different classes, varying in thickness, as in the case of the French slates, from $\frac{1}{8}$ in to $\frac{3}{16}$ in.

Fire-clays are wrought in the province of Namur, varying in color, from an almost perfect white, to dark bluish grey, and reddish brown. Fire-proof bricks, of a superior quality, are priced at from 32s. to 40s. per ton. Hearth blocks for welding furnaces fetch as much as 64s. per ton. Fire-bricks, from the province of Liege, are compressed by hydraulic pressure, and afford a dense, compact material at a reasonable price.

The bricks of Holland are described as sound and durable, though not, as a rule, well finished. The corners are rounded, and the surface coated with sand. They appear to be well burnt through, without vitrification on the outside, and are dense and very hard. The largest size is $8\frac{5}{8}$ inch by $4\frac{1}{8}$ inch by 2 inch; and the price varies from 20s. to 40s. per 1,000. The second size is $6\frac{1}{4}$ inch by $6\frac{7}{8}$ inch, by $1\frac{3}{16}$ inch; for which the price is from 8s. to 10s. per mille. Clinker bricks are supplied for paving. It is worthy of remark that the prices of machine-made bricks are 2 or 3 per cent higher than of those which are made by hand.

Wall-tiles of white, pale blue, and lavender, of the well-known old Dutch patterns, vary in price between 60s. and 80s. per thousand. The usual size is 9 inch by 6 inch. Millions of these tiles are made annually at Utrecht, a little under 5 inch square, and costing from 8 to 10 centimes each, or about 64s. per thousand. They are also produced in finer qualities, at prices from 60s. to 68s. per thousand.

Denmark has shown but little of its building products, Messrs. Erichsen's roofing tiles being almost the sole exhibit. These are solid, flexible, and perfectly adapted to the requirements of the builder. Sweden only exhibited small specimens of her rich and varied stores of building-stones, granite, porphyry, marbles and limestones.

The varied and inexhaustible wealth of the Italian peninsula, in all that forms the material of the builder, the sculptor and the decorator, was well and completely represented at Vienna. The Italian Minister of Agriculture, Industry and Trade, exhibited a fine collection of stones for building, quarried and worked in Italy.

The physical conformation of the Spanish peninsula is such as to leave little room to doubt that the mineral products of that country are in no way inferior to those of Italy. Indeed, in the neighborhood of Logrono, there is said to occur excellent coal, while bituminous shale is the only combustible mineral with which we are acquainted as native in Italy. Many specimens of building-stone were sent from Spain, chief among which may be noted magnificent specimens of pure alabaster from Guadalajaro. Fine dark-colored slate is found in the same province. Marbles of various kinds are quarried in the Balearic Islands; and hydraulic limes and cements are also produced in Spain. Encaustic tiles, manufactured by Signor Nollo, of Valencia, are exported in large numbers to Italy and to South America. Messrs. Soto y Tello, of Seville, manufacture tiles colored with white, green, blue and black, made after designs taken from the works of the Alhambra, in the repairs of which building they are employed. Nothing, however, of merit approaching that of the famous Buen Retiro *faience* was forthcoming from Spain in 1873. In Portugal, mining industry has of late taken a fresh start, under the impulse given by a modification of the laws regulating mines and quarries. Marbles were exhibited from Estremas, and very fine

dark slates, some of which were almost black, are found in the district of Oporto.

The most numerous and most complete series of exhibits of building materials to be seen at Vienna came, as was naturally to be expected, either from the Dominions of the Austrian Emperor, or from those of his German brothers. Under the latter head, the Mining Commission of Alsace and Lorraine contributed a fine collection of some 180 specimens from the quarries of these provinces. These comprehend granite, gneiss, porphyry, various sandstones, limestones and marble. The dark yellow sandstone found in the vicinity of Halle was represented by a large lion, sculptured from the material. A grey sandstone from the same exhibitors was formed into a pedestal supporting a bust of the Crown Prince.

The granite from Silesia is remarkable for its excellence. A carefully-wrought slab, 16 feet long, 12 feet 4 inches wide, and 7 inches thick, was sent from Saarau, in this district. The slate quarries of Lehesten have been carried on since the tenth century. The color of the slate is dark blue, and its imperishable character is explained by the chemical analysis, which shows 64 per cent. of silicic acid, 17 per cent. of alumina, and 13 per cent. of various oxydes, combined with 4 per cent. of water, and but little more than 1 per cent. of carbon and carbonate of lime; the slate is fine in grain and regular in cleavage, producing plates as thin as .04 inch. The price also is low, and the consumption very large.

The Saxon serpentine, from the stone works of Zoblitz, appears to be free from the usual defect of this very beautiful material; a defect to which the serpentine of our own south-western district is liable, namely, the numerous cracks that divide the mass, rendering it impossible for the quarrymen to extract large and sound blocks. In the Norman, and also in the Florentine work, in which this material is used, the pieces are very small. The Zoblitz Company, however, produce not only large blocks, but veneers for covering surfaces of stone, and their work has attained a high degree of excellence. The usual color of this serpentine is a dark green; but black, red and yellow varieties also occur, and are used with good effect in mosaic.

The "cajalith" of M. Schmidt, of Dresden, is a beautiful artificial building material, the composition of which is kept secret by the inventor. It is nearly white, fine in grain, and closely resembles marble in appearance. When first made it is plastic, and may be moulded into any required form. It subsequently sets, and becomes extremely hard. It can also be made of any desired color, but the specimens of mosaic formed from cajalith, made in imitation of various natural stones, had suffered from exposure to the weather. As much as 50 tons of this material is now produced per month.

A tufa, found in the vicinity of the Laacher Sea, near Andernach, is interesting as showing the appearance, in this region, of this light, durable, volcanic material, which cuts with almost the facility of chalk; and to the abundance of which, in Italy, the introduction of the vault, as an architectural feature, may with great justice be attributed. The Andernach tufa, however, is blue; that of the South of Italy is of a pale yellowish brown. The analysis of the former shows it to contain 52 per cent. of silicic acid, 15 per cent. of alumina, and 11 per cent. of sesquioxyde of iron. It has been used since the time of the Normans, for the manufacture of hydraulic cement. As many as twenty-five cement-makers competed at Vienna from Germany. The tertiary clay, and the chalk, of Rügen and Stettin, and the deposits near the mouth of the larger rivers, as for instance near Emden, which are analogous to those of the Medway, are used for this manufacture. Light yellow bricks, inlaid tiles, glazed decorative plates, terra-cotta columns and capitals, a terra-cotta statue of Germania, mosaic tiles for pavements, fire-bricks and blocks for blast-furnaces, large clay retorts, up to the weight of 1½ ton, glazed tiles, and white Dutch tiles, gilded and brightly enamelled, are exhibits which say much for the industry of the clay-workers of Germany.

Artificial-roofing materials are also much in use in Austria. There were twenty-three exhibitors of felt, paper, wood and various cements, for this purpose. Herr Irmes, of Berlin, works up 1,500 tons of raw material into roofing material per annum. Zinc plates, color-

ed red, black and white, in imitation of tiles, were taken from a roof in Munich, where in twenty-seven years they had suffered but little loss of weight. Considering, however, the conducting power of metal, the instances can be but few in which a wise architect would substitute a thin zinc plate for a sound and impervious tile.

The building-stones of Austria are numerous and excellent. White, light grey, blue and yellow varieties of limestone are quarried in the Vienna basin. The Wöllersdorf stone is distinguished for great hardness and purity of color. The Mühlendorf limestone is of a similar quality, although in places it contains crystals of dolomite. A blue and yellow stone, from Sommerin, extremely hard in its lower bed, is known as Imperial stone. A fine white statuary limestone is found in the neighborhood of Neusiedeler. A fine sandstone, which has been used in the restoration of the Cathedral of St. Stephen, at Vienna, is from St. Margarethen. A fine red sandstone, variable as to quality, is quarried at Brun am Steinfeldt, and also at Baden. The Vienna or Karpathen sandstone is of a bluish-grey color, with a fine quartz base, cemented by lime and clay. It disintegrates by exposure to the atmosphere.

Marbles are found in Carinthia. Quarries of a dark red marble have recently been opened at Arnoldstein. A light-blue marble-like stone, with dark veins, which takes a high polish, and a fine-grained white and reddish limestone, with green veins, are largely used. Tufaceous limestone is also frequent in Carinthia. It is light, and easily quarried. Most of the slate used in Austria comes from the Silesian and Moravian provinces, which possess good qualities of green and of dark blue slates.

In the Lengau Valley about 30,000 tons of materials are annually worked up into hydraulic lime and cement. In Vienna, 50,000 tons of cement and hydraulic lime, and 12,500 tons of gypsum, are annually made and sold. Near Steinbrück, in Styria, an argillaceous marl slate and a dark blue limestone have been quarried for the same purpose for fourteen years. Building blocks, composed of broken stone and cement, are manufactured at Vienna.

The brick industry of Austria is also very active, a thousand million of bricks having been turned out from the various factories in 1870. The Wienenberger bricks, from their acknowledged excellence, are chiefly used for public buildings. The Wienenberger Company produce also tiles and objects in terra-cotta, and it is said to be owing to the magnitude of these works that the building for the Exhibition of 1873 was completed in time.

THE "BESSEMER."

From "Engineering."

THE steamship "Bessemer" made her first public trip across the Channel, May 8th, carrying as passengers a large party who had accepted the invitations to a trip to Paris issued conjointly by the London, Chatham, and Dover Railway Company, the Bessemer Steamship Company, and the Northern Railway Company of France. A special train from the Victoria station conveyed the passengers to Dover, and shortly after eleven o'clock the "Bessemer" steamed out of Dover Harbor on her way for Calais. Of course, one of the chief attractions which had drawn the company together was the swinging saloon, and hence much disappointment was naturally expressed when it was learned that the saloon was to remain fixed and was not to be worked at all during the trip, the reasons assigned being first that the gear for controlling the saloon was not completely adjusted, and second that no opportunity had yet offered for the man controlling the hydraulic gear to obtain that practice in working the machinery which is naturally essential to a satisfactory result. These are, of course, good reasons for leaving the saloon fixed, and we think that the company acted wisely in not working the saloon at all rather than run the chance of

working it unsatisfactorily. Trials of such a nature are far better made in private, as first experiments of this nature cannot be expected to be all successes, and the impressions of public failures are not easy to remove. Whether or not it would not have been more judicious to have postponed the public trial until the swinging saloon was ready to be shown in action is, however, another question, which it is scarcely necessary to discuss here.

Luckily there was really no want of a swinging saloon. With the exception of a slight fog at starting the weather was all that could be desired by a landsman making the Channel passage, while the sea was so calm and the "Bessemer" so steady that none but the most exceedingly qualmish were likely to suffer inconvenience. Under these circumstances the passengers, if they were disappointed in not witnessing the working of the swinging saloon, had at least the satisfaction of being able to appreciate the numerous comforts with which the "Bessemer" abounds—comforts which appear all the greater to those familiar with the accommodation existing on board the ordinary Channel steamers.

We have so recently published descriptions of the chief features of the "Bessemer" that it will be quite unnecessary for us to enter into any detailed account of the vessel here. We may mention, however, for convenience of reference that she is 350 ft. long over all, and 40 ft. actual beam, there being, however, a row of overhanging private cabins down each side between the paddle-wheels, which increase the apparent beam to 54 ft. On deck the length is 270 ft., the low pointed ends which form such a prominent feature in the design making up the remainder of the length. The "Bessemer" is propelled by two pairs of oscillating engines driving feathering paddles 30 ft. in diameter, the two pairs of wheels being situated at a distance of 106 ft. apart from centre to centre, with the swinging saloon between them. The after wheels have, of course, to act upon water which has been previously put in motion sternward by the forward wheels, and hence the former wheels run slightly quicker than the latter. On May 8th the difference in speed of the two pairs of wheels was almost exactly two revolutions per minute, the former wheels making 25½, and the aft wheels 27½ revolutions per minute for the greater part of the trip. The difference in speed of the two pairs of wheels was thus about 8 per cent.

The engines of the "Bessemer" were put on board before the vessel was launched, and to this probably is, to some extent, to be attributed their present state. At all events they are at present, to use a workshop term, considerable "out of truth," this being particularly the case with the pair which were aft during the run from Dover to Calais, and the result naturally being hot bearings. Apart from the defect just mentioned the engines are of plain substantial design, and we trust that they will eventually be put in proper condition. As regards the pressure of steam maintained, state of the vacuum, and indicated power developed during the trip we have no data, and we believe in fact that the engines have not yet been subjected to any regular trial to prove their capabilities.

On May 8th the run from Dover to Calais was made in an hour and thirty-three minutes, and it unluckily terminated by the vessel destroying a portion of the western pier of Calais. As those familiar with Calais harbor well know, the chief pier is situated on the eastern side, the western pier being a much lighter structure. There was a strong tide setting eastward across the mouth of the harbor; and the "Bessemer" was accordingly made to approach the mouth slightly from the westward, port helm being given to cause her to enter the harbor. As she came between the piers the helm was, we believe, steadied and then placed to starboard, but as the vessel lost way the effect of the starboard helm was unnoticeable, and under the influence of the transverse current the stern still paid off to the eastward and the bow to the westward, the result being that the vessel ran into the western pier, completely clearing it away for some 100 ft. or so. The shattering of the pier timbers was a mere trifle to the "Bessemer," the shocks experienced on board being scarcely perceptible, while the only damage the vessel sustained consisted in the removal of a few splinters from the sponsons at the bow and

the carrying away of the foremast in consequence of the pier coming in contact with the wire rope stay. A few minutes after the disaster the "Bessemer" was laid alongside the eastern pier without difficulty, and after partaking of a luncheon provided at Calais station, her passengers proceeded on their way to Paris by special train.

The behavior of the "Bessemer" in entering Calais Harbor has naturally given rise to grave doubts as to whether or not the vessel will be ever placed regularly on the Dover and Calais service. She has now paid three trips to Calais, and on two occasions out of the three she has come into contact with the piers, the entrance on the second occasion being made without difficulty. So far, too, she has had the benefit of fine weather, and how she can be got into Calais with a high sea running has yet to be proved. Her commander, Captain Pittock—well known for his experience in the Channel service—is, we are certain, able to do all that can be done in the matter, but whether further experience will enable the vessel to be successfully handled in such a harbor as that of Calais has yet to be proved. A report has been circulated in some quarters that on May 8th the hydraulic steering gear (Brown's patent) did not act properly at the critical moment; but for this report there was, we have every reason to believe, not the slightest foundation. The gear, in fact, appears to be all that can be desired. It is to be remembered, however, that with this, as with other mechanical steering gears, the motion of the rudder is not absolutely synchronous with the motion of the steering wheel. The former follows the latter faithfully, but it follows it at a very brief interval of time—an interval not noticeable in fact under ordinary circumstances, but of importance perhaps under certain conditions. This being so, it would, we think, be an advantage if there was provided a tell-tale worked from the rudder and showing the actual position of the latter, this tell-tale being situated so that it could be readily seen by the captain or officer conning the vessel, who would thus have positive information afforded him as to the helm which was being given. With a long, shallow vessel such as the "Bessemer," the helm necessary to effect any desired movement has, of course, to be given earlier than it would be with a shorter vessel, and how much earlier is a mattter which only experience can determine, so that it is quite possible that further practice may materially improve the control obtained of her movements in a narrow entrance and under the action of cross currents.

Another point yet to be determined is the effect of the bow rudder. Up to the present time no experiments have been made on the effect of employing the rudder situated in what is for the time being the bow, to assist that astern; but we think that some trials of this kind should be made, and are inclined to believe that under the influence of cross currents the action of the bow rudder would be especially beneficial. This, however, is—like the other points to which we have referred—one on which it is useless to theorize, as it is one regarding which experience alone can give information of value. In leaving this subject for the present we may remark that when fairly under way, the "Bessemer" answers her helm well, and there appears no reason whatever to grumble regarding her steering qualities so long as she is moving through the water at a fair speed.

The return trip was made on May 10th, a special train conveying the passengers from Paris to Calais, and a start being made from the latter place to Dover, at 3 p. m. The run from the actual start at Calais to the vessel being laid alongside at Dover was made in 1 hour and 46 minutes, and the run from pier head to pier head in 1 hour and 44 minutes. The "Bessemer" was not turned for the return trip, and the end which on May 8th was the bow was thus on May 10th the stern, and *vice versa*. The difference between the speeds of the two engines was the same as during the outward passage, the actual speeds during the trip being 26 per minute for the pair which were for the time being the forward engines, and 28 per minute for those aft. The bearings proved to be in better condition on her return trip, and although they still heated, the heating was very much less than during the outward trip, and it was necessary to run water on them. On her arrival at

Dover the vessel was brought alongside the Admiralty Pier in a manner which elicited from the passengers three hearty and well-deserved cheers for Captain Pittock, and shortly afterwards a special train conveyed the passengers to London.

Thus ended the first public trial of the "Bessemer"—a trial which was certainly not without interest, although the great feature of the vessel, namely, the swinging saloon, remained untested. The weather, too, was so fine that the seagoing qualities of the vessel were but very little tried; but there is, nevertheless, every reason to believe—judging from such experience as has been already gained—that they will be satisfactory. As regards speed the prospect is not so promising, the times occupied in the runs on both trips showing that the "Bessemer" is at present certainly not a fast vessel.

To what extent this result is to be attributed to the excess of draught above that originally intended, or how much may be due to the non-development by the engines of the proposed power, it is at present impossible to say; but it is much to be hoped that such experiments may be carried out as may afford some information on this head, as any data of this kind referring to a vessel of the peculiar build of the "Bessemer" have a special interest. We shall, no doubt, before long have more to say regarding the "Bessemer" and her capabilities; but in taking leave of her for the present it is only just to add that whatever speed she may ultimately attain and whatever may be the results of the trials of the swinging saloon, the vessel offers admirable accommodation for passengers, and the comforts which she affords can scarcely fail to be appreciated by the traveling public.

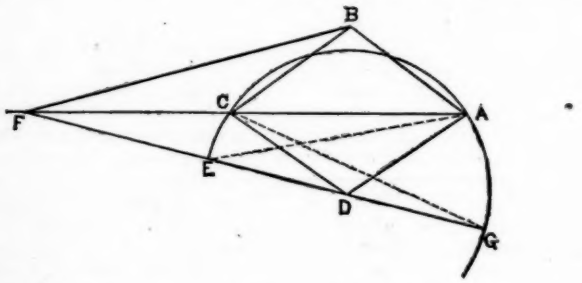
AN ANALYSIS OF THE PEAUCELLIER COMPOUND COMPASS.

By WALTER SCOTT.

Written for Van Nostrand's Engineering Magazine.

Having constructed a Peaucellier Compound Compass, and being compelled to work out for myself the formula for using it, I submit the result for the benefit of others.

Let P B C D A, Fig. 1, represent the outline of a "Positive Cell" instrument, consisting of the equilateral cell A B C D A, and the connectors B F, D F, of equal length. From the construction



of the figure, the points F, C, A, are in the same right line. Let F A = V, F C = V', F D = F B = L, and a side of the inner cell = l. With D as centre and radius = D C = D A, describe the semicircle E C A G, and produce F D to G. Draw C G, A E. The angle F A E, F G C, being measured by the same arc, are equal, and since the < A F E is common the triangles F G C, A F E, are equiangular and similar, hence the proportion

FC : FG :: FE : FA; FC, FA = FG, FE.

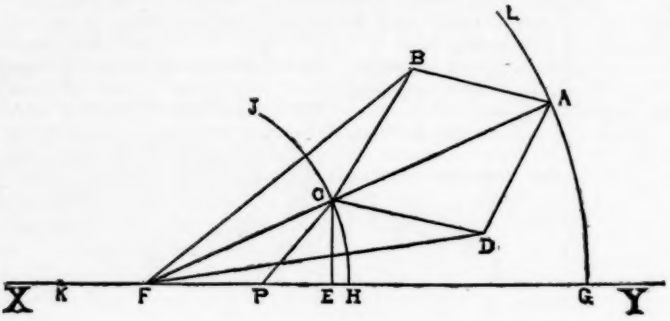
But FC = V', FA = V, FG = L × l, FE = L − l, hence

V.V' = (L + l) (L − l) = L² − l^2, that is,

the product of the arms FA, FC, is constant, and equal to the difference of the squares of a side of the greater and lesser cell.

If the point F be fixed as a fulcrum, and the point C be compelled to follow any curve given by its equation and relative to the point F, the curve described by the point A may be determined.

Let X Y represent the co-ordinate axis, and the point P the origin of the curve H C J in which C is constrained to move. Let the curve G A L, described by the point A, be referred to the fulcrum F as origin.



Let the radius-rector FA = V,
" " PC = v,
" variable angle AFG = d,
" distance FP = a.

Then $$FC = \frac{L^2 - l^2}{V} \quad (1)$$

$$CE = FC, \text{ Sin. } d = \frac{L^2 - l^2}{V} \text{ Sin. } d$$

$$PE = \sqrt{PC^2 - CE^2} = \sqrt{v^2 - \frac{(L^2 - l^2)^2}{V^2} \text{Sin.}^2 d}$$

$$FE = FP + PE = a + \sqrt{v^2 - \frac{(L^2 - l^2)^2}{V^2} \text{ Sin.}^2 d}$$

$$FC = \frac{FE}{\text{Cos. } d} = \frac{a + \sqrt{v^2 - \frac{(L^2 - l^2)^2}{V^2} \text{ Sin.}^2 d}}{\text{Cos. } d} \quad (2)$$

From eqs. (1) and (2) $$\frac{L^2 - l^2}{V^2} = \frac{a + \sqrt{v^2 - \frac{(L^2 - l^2)^2}{V^2} \text{ Sin.}^2 d}}{\text{Cos. } d}$$

Reducing and arranging this equation we have

$$V^2 + 2V \frac{a(L^2 - l^2)}{v^2 - a^2} \text{. Cos. } d = \frac{(L^2 - l^2)^2}{v^2 - a^2} \quad (3)$$

which is the general polar equations of the resulting curve G A L. From this general equation may be found the equations corresponding to any given generating curve.

If the generating curve is a circle with centre P and radius PH = r, the radius vector PC becomes constant and equal to r, and equation (3) becomes

$$V^2 + 2V \frac{a(L^2 - l^2)}{r^2 - a^2} \text{ Cos. } d = \frac{(L^2 - l^2)^2}{r^2 - a^2} \quad (4)$$

The polar eq. of circle of radius R, passing through G, and referred to F as origin, is

$$V^2 + 2V\left(R - \frac{L^2 - l^2}{r + a}\right) \text{ Cos. } d = 2\,\frac{L^2 - l^2}{r + a}$$

$$R - \frac{(L^2 - l^2)^2}{(r + a)^2} \quad (5)$$

Comparing eqs. (4) and (5) it appears that eq. (4) is the eq. of a circle whose radius = $r \cdot \frac{L^2 - l^2}{r^2 - a^2}$, hence if the point C moves in a circle whose radius = r, the

point A will describe a circle whose radius

$$R = r.\frac{L^2-l^2}{r^2-a^2} \qquad (6)$$

In eq. (6) if $r=a$, the value of R becomes infinite, showing that the resulting curve G A L becomes a straight line. Hence by causing the generating circle to pass through the fulcrum the famous problem of parallel motion is solved.

When r is greater than a, R is positive, and the resulting circle will be concave toward F and enclose it.

When r is less than a, R is negative, and the resulting circles will be convex toward F, and fall outside.

If in eq. (4) we make $d=0$, we have $V=\frac{L^2-l^2}{r+a}=FG$, the distance from the fulcrum at which the curve cuts the axis.

If the length of the radius bar P C be fixed the required length of F P can be found necessary to give the resulting curve any given radius, or, conversely if the distance F P is fixed the required length of radius bar can be found. From eq. 16

$$R = r.\frac{L^2-l^2}{r^2-a^2}, \text{ from which we find}$$

$$r=\frac{(L^2-l^2)\mp\sqrt{(L^2-l^2)^2+4\ R^2\ a^2}}{2\ R}$$

$$a=\sqrt{\frac{R r^2-r\ (L^2-l^2)}{R}}=\sqrt{r^2-\frac{r}{R}\ (L^2-l^2)}$$

If the sides L, l, are respectively 15 and 5 inches, and the radius bar $r=10$ inches, then $a=\sqrt{100-\frac{2000}{R}}$ inches. If R=200 inches, $a=9\frac{1}{2}$ inches, nearly.

If the generating curve H J is an Ellipse, Parabola, or any other plane curve given by its equation referred to P_1, the resulting curve G L can be determined in the same way, and, conversely, if any given curve G L is required to be traced by A, the generating curve necessrry to develop that curve can be found.

THE ORES OF IRON CONSIDERED IN THEIR GEOLOGICAL RELATIONS.*

From the "London Mining Journal."

In addressing an audience like this Institute, composed of men to whom the subject matter is familiar, the lecturer has the advantage of being able to dispense with most of the usual introductory explanations. I will, therefore, with the concurrence of my hearers, assume that it is unnecessary to dwell upon the special characters of the different ores of iron, further than to accentuate those in particular upon which my later statements and arguments in to-night's discourse will mainly depend, omitting the discussion of certain silicates, rarely employed for smelting, and of iron pyrites, the recent technical history of which has introduced to us a new purple ore on a large scale. The ores of iron to which I would invite your present attention are simply the oxides, as met with *per se*, or combined with water, or with carbonic acid—the substances, in fact, which form the great bulk of the material employed for the production of the metal.

When we observe the various results of analysis, or even carefully look into the actual samples of ore, there are often anomalies noticeable where not expected, often two or more kinds mingled together, and giving intermediate results; but I hold it not the less desirable that, as far as possible, we should fix the characters of certain species, hold fast to them through their sundry minor variations, and learn how to follow the clue when these substances are found to pass distinctly from one specific condition to another. I would, therefore, pass under review these important ores, to impress their individuality on the memory, and would then consider some of the changes

* Read before the Iron and Steel Institute, by Prof. Warington W. Smyth, F. R. S.

which nature in many cases has wrought in them, and which sometimes may even need to be noticed in the smelting process, but which very generally will have to engage the attention of the explorer and the miner.

Magnetite.—First in order, if we omit from the elementary metal, which, as such, is a rare and often disputed constituent of the earth's crust, we recognize magnetite, or magnetic iron ore, by its octahedral crystallization, often taken partially or entirely the form of the rhombic dodecahedron, but even when almost compact betraying its crystalline form by the brightness of the triangular faces; further, by its black color, and black streak, and its magnetic property after showing polarity.

This mineral, $FeO + Fe_2O_3$, with 72.41 per cent., when pure, is the fine rich ore which Dannemora in Sweden, Arendal in Norway, and several other mines in Scandinavia, have worked with great success for centuries from elongated deposits which are neither lodes nor true strata. It is mainly this ore which forms the vast mass at Gellivara, in Lapland, apparently on a larger scale than any other known agglomeration of iron ore; this it is also which is the chief constituent of the remarkable protrusions boasted of by the Uralian metallurgists, the Katschkanar, the Blagodat, near Kuschwinsk, and the Vissokaya Gora. In Italy, fine examples of magnetite are those of Traversella, in the Piedmontese Alps, and that of Cape Calamita, in the Isle of Elba. In North America, the older stratified rocks, both Lawrentian and Huronian, in Canada, as well as in New York and New Jersey, abound in strips, beds, and masses of magnetite, which are concordant with the stratification, and, though by no means uniformly rich, are sometimes wondrously massive. These have been opened out in hundreds of mines, and are, doubtless, destined to play a great part in the iron trade of the United States.

In Great Britain, a few localities can only be quoted as offering magnetite in workable quantities. A small vein near Penryn, in Cornwall, and another or two near Roche, and, perhaps, that of Ballycoog, near Arklow, ought to be available in favorable times; while a singular series of several successive beds exist at Hey Tor, near Bovey, in Devon, which has only now in these last few weeks been placed in working position. (Mr. Smyth here submitted a section of these remarkable crystalline deposits, as showing on the line of cross-cut level a thickness worthy of attention, and a mode of occurrence bearing strong analogy to some of the Scandinavian mines.)

The minutely crystalline magnetite, which occurs in the north flanks of Aran Mowddy and of Cader Idris, in North Wales, has never yet been opened out with perseverance, and the objection to some of it, that it is pyritous, is to be met by more careful selection.

Hematite.—The second species is the well-known hematite, termed specular ore, or oligist when crystallized, red or kidney ore when in a compact or fibrous condition. This substance $Fe^2 O^3$, with 70 per cent. of iron in its state of highest purity, too well known to need description, and an important ingredient in the trade of most of the ironmaking countries, is distinguishable in most cases instantly if not by its external aspect, by the blood-red streak, which is sometimes difficult to produce on surfaces as hard and as smooth as polished steel, will appear even though the color of the outside be purple or black. The value of this ore, so little recognized thirty years ago, is now too well known for me to enlarge upon. Its strange occurrence in Furness and near Whitehaven has been well described in the pages of your journal, and a very curious parallel to the northern mines may be found on a smaller scale in the numerous deposits, partly of red and partly of brown hematite, which have for years been worked in the Mendip Hills.

I have to thank the proprietors and agents of two of the most remarkable of these mines for enabling me to place before you to-night the plan and section of the Roanhead and Park doposit, and those of the Hodbarrow mine. There could not be better examples of the entire irregularity of form assumed by these vast masses, of their great productive capability, and of the well-merited success due to the unsparing use of the boring rods.

In our western districts, as near St. Austell and at Exmoor, hematite occurs in veins, not generally large, but exhibiting

some splendid ores, and showing, where they intersect the clay-slates, an analogy with the rich district of Siegen in Prussia, also situated on the rocks of the Devonian system.

There are cases in which these ores are certainly of a bedded character, as in Canada, and at La Marquette in Michigan, where very extensive workings have proved certain strata, mostly made up of this ore, to be from 50 ft. to near 100 ft. in thickness. Probably those of Bilboa may be thus stratified. The Americans seem mostly to ascribe an intrusive origin to their great masses of red ore in Missouri, the well-known Pilot Knob, and Iron Mountain; and the magnificent displays of ore in Elba, some seven in number, occurring in a straight line, are regarded by numerous authors as of volcanic origin.

In fact, when observers have been familiar with the marvelous production of crystallized specular iron by sublimation from the neighboring volcanic vents, it is easy to lean to the belief of its being connected with the volcanic influences in Elba.

Bauxite and Wo-ehnite.—The curious ores to which the names of Bauxite and Wo-ehnite have been given, in which alumina, Al^2O^3, take the place of much of the sesquioxide of iron, deserve special mention, from the fact of the Irish variety being so largely employed in the smelting of hematites. Mr. Snelus has kindly supplied me with analyses of some of these ores in practical use, which, with the percentage of 58, 34.37, and 28.93, of peroxide of iron, contain respectively 17.89, 39.20, and 45.75 of alumina.

Turgite.—Next, we have an ore called Turgite, after the mine of Turginsk, in the Ural Mountains, $2\,Fe\,O^3 + H^2O$, an oxide of iron, with 5.3 per cent. of water, of brownish color, but with bright red streak; otherwise with fibrous structure and mammilated surface, looking much like the botryoidal hematites. We know but little about this species, yet it doubtless occurs largely among the brown ores which come to the furnace. It is quoted as found at divers European localities, especially Horhausen in Nassau; and it has been met with at the Restormal Mine, in Cornwall. A compact black ore now being raised at that mine, gave to Mr. Ward, of Dr. Percy's laboratory, only 3.25 per cent. of water.

Go-thite is the name generally given to the definite compound $Fe^2\,O^3 + H^2O$, in which 10 per cent. of water is added to the ferric oxide. One of the varieties, Lespidverokite, is translucent and red by transmitted light; another "needle iron ore," brilliant, but only slightly translucent; a third, wood iron, opaque and fibrous; a fourth, brown or black ore, opaque and with no regular structure; but, from the splendid prismatic crystals of Lostwthiel downwards, all these varieties have a brown streak. The most notable examples of these ores in our own country are at the Restormel Mine, in Cornwall, on Exmoor, on the Brenden Hill, in the Mendip, near Bristol, and in the Forest of Dean; but there are very numerous places, at home as well as abroad, where, amidst the ores called in the large scale brown iron, or brown hematite, a portion will prove to be this monohydrate, whilst other parts of the same deposit may, very likely, belong to the next following species. The name of stilpnosiderite has been given to a mineral with a lustrous pitchy fracture, but it is somewhat uncertain as to whether it belongs to the above-named division.

Limonite, $2\,Fe^2\,O^3 + 3H^2O$, with iron 59.9, and water 14.4 per cent. A large proportion of the "brown iron ore," or that which gives a brown streak, belongs to this series, but both the external contour and the structure are very variable. The fact of the brown ores being often met with in the shallower parts of repositories, which may contain other substances in depth, is an explanation of their having been largely explored and worked from a very early period. Thus, as a stratified rock limonite it may sometimes in great thickness be followed downward a long way without change, as in the mines near Elbingerode, in the Hartz, or it may change downward into the impure carbonate, as in the Lias and Oolitic strata. When, in veins, it will commonly be found to constitute a sort of gassan or iron-hat, fated to yield to other minerals in depth.

In the Alston Moor district, hitherto but little worked, it is observable that the "rider" of the lead lodes often shows itself at surface in a great mass

of brown ores; and similarly, in the central part of Cornwall, between Par Station and Ladock, a number of lodes, apparently continuous in their course, with veins bearing elsewhere copper and tin ores, carry, as they approach, and, in some cases, enter the granite rock, brown ores in considerable abundance.

To illustrate the different conditions of hydration and admixture in brown ores from the same locality, I am enabled, by Messrs. Snelus and E. Jackson, to compare two examples of the ore so largely imported from Porman, near Carthagena:

	No. 1.	No. 2.
Peroxide of iron	83.80	74.85
Alumina	.50	3.00
Oxide of manganese	Trace	0.83
Lime	——	1.69
Magnesia	——	0.55
Silica	1.50	8.60
Sulphur	.20	0.21
Phosphoric acid	.07	0.14
Combined water	14.00	10.17
	100.07	100.04
Metallic iron	58.6	52.40

No. 1, a particularly lustrous, stripy ore, would thus approach limonite; No. 2, Gothite in its composition.

Xanthoriderite, or yellow iron ore, $Fe^2O^3+H^2O$, with 18.4 per cent. of water. This ore is of a yellowish color, sometimes in silky fibres and needles, in other cases more like an ochre; but it is cited definitely from only a few localities; and from the character of the occurrence, so commonly in successive incrustation, it is difficult with many of the substances called "morass," or "bog iron ore," etc., to feel assured where the line should be drawn.

Chalybite, Siderite, White Iron Ore, Carbonate, Spathic, Spathose, or Sparry Iron. FeO, CO^2, with 62.1 of protoxide of iron. Such a percentage would give 48.22 of metallic iron; but this is an ore which almost invariably contains, in lieu of some of the iron, a notable amount of manganese, calcium, or magnesium. The rhombohedral crystallization and the crystalline structure are sometimes minutely, but often largely lamellar, both outer and inner planes often curvilinear, with its light shades of color so readily heightened by exposure, these are tolerably distinct external characters. It is only, however, within the last twenty-five years that inquiries after steel irons, and more recently after the means of making spiegeleisen, have attracted attention to it in this country, and have led to extended observations like those read by Mr. Smith to your Institute a year ago. The late Mr. Charles Attwood was the first to utilize the considerable quantities of this mineral present as "rider" in the ironstones of many of the lead mines in Weardale and other parts of the North. In the granite of Foxdale, in the Isle of Man, in the great cross-course lead lode of Frank Mills in Devon, and in many of the Cornish mines, the admixture of chalybite with other ores is often on a large scale, but its value is commonly marred by difficulties of carriage. More important is the range of veins occupying a length of some 30 miles in Somerset and North Devon, from the Ebbw Vale mine of Raleigh's Cross westward, to near Ilfracombe. Nor can I omit to mention the fine lode of Perran, sometimes 100 ft. across, if taken horizontally from wall to wall, where workings, commenced in brown ore, have opened downwards, at depths of from 30 ft. to 120 ft., into large masses of chalybite.

The varieties of ironstone in which the carbonate is mingled with a very variable amount of clay, of lime carbonate, or of carbonaceous matter, are thoroughly well-known to my hearers from their wide diffusion over this country, and their commercial importance. They are, in fact, objects of more interest to the smelter than to the mineralogist. Certain of these, as the celebrated Cleveland ore, date their employment from a very few years ago; others, like the dark pisolitic masses of the pulverzoic schists of Anglesey and North Wales, have hitherto met with but little attention.

Let us now, in order to see more clearly the relationship between these several oxides, examine a few typical specimens, taken from localities where the development may be studied on a large scale. I place on the table a piece of what looks like chalybite or spathic ore, from Hüttenberg, in Carinthia; it is covered with large rhombohedral crystals characteristic of that ore, and through the mass may be traced lines showing the tendency to rhombohedral cleavage. But it is chalybite no longer; the brown streak,

the presence of water, and the percentage of iron, prove it to have been changed into brown ore. Here is a fragment from the lodes of the Deer Park in Exmoor; the cellular mass is pervaded by lines still exhibiting distinctly the rhombohedral structure, but the rich brown color, and the innumerable array of brilliant needles of Göthite, show that this, too, has lost its carbonic acid, has acquired oxygen and water, and actually become a different substance. The first stage of the change may be observed in heaps exposed in the shaft tips even for a few months; a brown tint, heightening with time, takes the place of the yellowish grey, and shows that a chemical action attacks the exterior and proceeds towards the interior. Similarly, at Raleigh's Cross, that well defined lode, in places over 20 feet in thickness was found at from 25 to 30 fathoms deep (vertically) to yield lumps of cellular ore, with kernels of undecomposed spatic, and thence down to the bottom of the mine, this latter ore in greatly increased proportion. In the great Perran lode, near Truro, the entire mass, sometimes for a few feet in depth, in other places down to 10 or 20 fathoms, is proved to consist of brown ores, which then begin to show nuclei of undecomposed chalybite; and lastly, solid masses of that mineral.

It has been argued by some that the change commences with the formation of the more hydrated species, and passes through successive stages to those with the least amount of water; but on this point the evidence is as yet defective.

The brown ores are undoubtedly (for one may watch the process in old workings) formed by another series of changes, from pyrites through the sulphate of iron. The crystals of brown ore, in the form of pyrites, are among the best known pseudomorphs, and there are localities which invite the inference that this action has taken place on an important scale.

Let us now proceed a step further. It was long since argued by Haidinger, that red ore is a pseudomorph after brown ore, and many instances were cited to prove that this change may generally be proved to have taken place. Unfortunately, the most notable example described, was that of specimens from Restormel. The highest authorities were called in to aid in the decision. Gustav Rose crystallographically showed that the forms of the crystals were those of Göthite; Rammelsberg proved that the substance was pure anhydrous oxide: I fear, however, that the whole phenomenon arose from the ingenuity of a roguish mineral dealer, who, by exposing the Gothite to a suitable heat, expelled the water, and thus manufactured deceptive specimens. But the fact is better borne out in other cases, and though difficult to prove in hard fragments, it has been shown by Morgans that a good deal of red ore was found in shallow levels of the Raleigh's Cross vein, which may probably have passed through the intermediate hydrated stage.

If we now examine a specimen from Bearland Wood, on Brendon Hill, another from Roger's lode, Exmoor, a third from the Eiserne Haardt, by Siegen, and a fourth from Somorrostro, at Bilbao, all analogous, we shall notice: first, that the large crystals are the rhombohedrons of chalybite; secondly, that the distinct cleavage of that mineral permeates the entire mass; thirdly, that the substance is pure red ore; and, fourthly, that this last crystallizes out boldly as specular. In all these cases, therefore, and innumerable others, even to a batch of ore brought by the indefatigable Livingstone from Central Africa, the hematite has indisputably been originally deposited as chalybite.

I dare not venture, in the present brief sketch, upon the vexed question of the original deposition of our great northern masses of hematite, although strong arguments for their having once been chalybite may be deduced from the occurrence of mountain limestone fossils turned into red ore. The half-way stage may be seen on the north side of Cross Fell, where, at Fox-fold, I have obtained fossils, now brown ore, which must in all probability have been changed *in situ*, through the intermediate stage of the carbonate.

There is still a last change of condition among the oxides of iron to be noticed. Is it not a significant fact, that magnetite is characteristic of the older formations of those bodies of rock which have, during the longest period of time, been exposed to the influences which bring about metamorphism and change of

substance? In the Perran lode small portions of magnetite have been found among the brown ores near the surface. In some of the Cornish copper lodes, notably in the Fowey Consols, specimens of magnetic ore have occurred, which look very much as if they had been carbonates. Among the beautiful red ores of Siegen, small grains of magnetite appear to testify to a partial change; and in the classical case of the mine, Alte Birke in Siegen, a singular black rather powdery substance, "eisenmulm," of which an example is placed before you, shows how the ore of the mine, in some places chalybite, in others red ore, is changed into an earthy magnetite. This, it is true, has been by some explained by the contiguity of a dyke; but without dwelling on the opposing arguments of Birchof, there appear to be sufficient grounds for believing that, in many cases at least, this last change in the degree of oxidation may be produced by the ordinary action of natural causes.

REPORTS OF ENGINEERING SOCIETIES.

Society of Engineers.—At a recent meeting of the Society of Engineers, a paper by Mr. Ernest Spon on "The Use of Paint as an Engineering Material" was read. The author, in the first place, considered the necessity for the use of paint, and then noticed the composition and characteristics of the pigments usually employed by engineers. White lead, he observed, should be of good quality and unmixed with substances which may impair its brightness. It is usually adulterated with chalk, sulphate of lead, and sulphate of baryta, the latter being the least objectionable. Zinc white is not so objectionable as white lead, but is dry under the brush and takes longer in completely drying. Red lead is durable and dries well, but should chemical action commence, it blisters and is reduced to the metallic condition. Antimony vermilion was suggested by the author as a substitute for red lead, and its qualities enlarged upon. Black paints from the residual products of coal and shale oil manufacture, and oxide of iron paints are generally used for ironwork, for which purpose they are peculiarly suited. Allusion was also made to anti-corrosive paints, and to those containing silica. Referring to the oils used in painting, the author stated that linseed oil was by far the most important, and that its characteristics deserved careful study. It improves greatly by age, and ought to be kept at least six months after it has been expressed before being used. It may be made a drier by simply boiling, or by the addition of certain foreign substances. Nut oil and poppy oil are far inferior in strength, tenacity, and drying qualities to linseed oil, and are used to adulterate the latter. The author noticed the driers employed, and alluded to the properties and means of testing the purity of spirits of turpentine. He then dwelt at length upon the mixing and practical application of paint to new and old woodwork, the preservation of cast-iron by means of Dr. Smith's pitch bath, and the cleansing, painting, and care of wrought-iron structures. He stated that when used under proper supervision no better protection could be found for iron structures than oxide of iron paints. He concluded by observing that the real value of any paint depended entirely upon the quality of the oil, the quality and composition of the pigment, and the care bestowed on the manufacture; and that the superiority of most esteemed paints was due to these causes rather than to any unknown process or material employed in their preparation.

At a meeting of the *Edinburgh and Leith Engineers' Society*, held at Edinburgh, a paper was read by Mr. Duncan Menzies, C.E., on the disposal of sewage. After briefly alluding to the methods of irrigation in use among the ancients, both as described by the sacred and profane writers, he proceeded to state the various modes of treatment at present in operation in different parts of England and Scotland. The result of careful observation proved that the application of sewage to land increased the value of the crops to a very considerable extent—land which was let originally at £1 per acre now yielding grass and other crops of the annual value of £30, and even more. Mr. Menzies then proceeded to describe some irrigation works near Craigmillar, which were laid out under his superintendence. The water of the Pow burn, which drains the south of Edinburgh, was led by main drains and cross-feeders on to fields, the soil of which was clay loam, well drained, and the result of three years' experience was that crops of from £17 to £21 per acre had been taken off, the annual value increasing with the longer application of the sewage. This sewage was necessarily very much diluted, as the natural flow in the Pow burn was great in proportion to the number of houses draining into it; but in spite of the weakness of the irrigation water, the result was highly satisfactory.

At the ordinary meeting of the sanitary and social economy section of the *Philosophical Society of Glasgow*, Mr. James M'Intyre, Port Glasgow, read a paper on "A Scheme for Intercepting and Utilising the Sewage of Towns, and Preventing the Pollution of Rivers." His scheme included a sewer led along the banks of the river, having double tanks at intervals between the towns from which the sewage was drained. In these tanks the solid matter would be intercepted, and from them it could be lifted at intervals of several days, and distributed by means of branch lines to the railways, and so to the districts where it was required. Mr. M'Intyre described an application of this scheme to the Clyde, which would serve Glasgow and the towns above it.

Mr. Murray exhibited to the section a model of a self-acting machine for separating and utilising the sewage of Glasgow, in which he

proposed to spread out the stream of sewage going into the machine, so that its course would not be too rapid, and to strain off the solid matter on the way. He proposed also to purify the water by means of filters of charcoal, or some other deodoriser.

In the course of a discussion on the papers, Mr. Deas, C. E., remarked that the fall along the banks of the Clyde was not sufficient for working Mr. M'Intyre's scheme. If he could overcome this and deodorise the water, the plan would be a capital one. Mr. M'Adam said that all attempts to make the solid matter got from sewage of commercial value had failed. Mr. James Brown observed that Mr. M'Intyre's scheme was substantially the same as one which he himself proposed twenty years ago. Mr. Gavin Campbell contended that sifting the solid matter from the liquid in sewage was simply nonsense. The best way to separate the two was by means of lime. Mr. M'Intyre having replied.

Mr. W. P. Buchan described a self-acting sewage gas-trap, a specimen of which he exhibited. The ordinary trap put into water-closet cisterns he showed to be defective, from the fact that the egg-shaped receptacle which was usually filled with water to trap the gas often dried up, and the gas had then free access to the cistern. Mr. Buchan's trap is so constructed that every time the water rises in the cistern a new supply of water rises into the trap, and it is thus kept constantly closed against the ingress of sewer gas by about an inch of water.—*Iron.*

THE AMERICAN SOCIETY OF CIVIL ENGINEERS.—This Society convened at Pittsburg, according to the programme announced last month. We extract from the *Tribune* the following discussions of the meeting of the 10th of June:

With the greatest unanimity of feeling, there is a wide ground for difference of opinion among civil engineers on what is known as the Bridge Question. It is an outgrowth of the bridge accidents of last year, which a committee of bridge builders belonging to the Society of Civil Engineers took into consideration. They brought in a majority and three minority reports, and ever since the bridge business has been a vexed question. The disagreement is as to the means of preventing such accidents. The majority of the Committee favor the adoption of a standard—that all bridges should be built to carry not less than a certain number of pounds per square foot; the number being fixed in tables, with reference to span and the uses to which different classes of bridges are subjected. These tables would require bridges which are unquestionably within the limits of safety. But the opponents of this proposition say that no account is made by it of the difference in iron or other materials. If the best iron, for instance, is by this restriction to be used in the same abundance with the worst, there is no object to be gained by using the best, and the result would be either that the rule would be ignored or inferior materials would be everywhere used. Gen. Ellis, discussing the subject said that the Committee seemed to be unanimous as to the load which ought to be used to test a railroad bridge: two heavy locomotives and a train of cars loaded to the maximum.

Mr. Herschel advocated the plan of subjecting the iron used for bridges to specific tests. The fact that such tests would be applied would cause contractors to furnish good iron. Mr. Clarke, engineer of the Phenixville Bridge, said that Western people were urgent that a standard of strength for bridges should be fixed. But if the State was to select experts to decide upon bridges the whole business would become, too soon, a mere political placer. There was discussion over the mathematics of one of the reports, and they were explained by Mr. Macdonald. But he thought that if the strength of the iron used was to be taken into account, the limit of its elasticity was a far more important factor than its breaking strength; he named an instance where the former was only one-half the latter.

Mr. Macdonald urged the adoption of the majority report on preventing bridge accidents. He would somewhat modify it, and he proposed that a Committee of three be appointed to report whether legislation on the subject should be recommended.

Mr. Ellis spoke of the difference of iron used in various localities. The English factor of safety in bridges was one-third; ours only one-fifth. Mr. Herschel said that France, Prussia, England, and some minor European States had adopted laws respecting bridges defining the strain they must bear to the square inch; since those laws went into force no bridge accidents had happened in those States. The public demand of the engineers of this country a similar protection.

Mr. Richard H. Buel, of New York, not being able to meet with the Convention, sent to the Secretary a paper which was read, containing a severe criticism upon the report of the Committee on Rapid Transit. To this Mr. Collingwood replied that the Committee had not found any practical scheme of rapid transit on a paying basis, but they did not propose to select any one scheme as the best, since some of the plans came from members of the Society. This morning Mr. Wm. H. Searles, of New York, resuming the debate upon this subject, said that an ordinary railroad is built only to accomplish a long journey in a short time; rapid transit requires high speed with stops at frequent intervals. Great loss of power is incident to frequent stops, and where the frequency increases the loss of power is even disproportionately augmented. In the case supposed, the maximum velocity between the stops must be 2½ times the average velocity of the train when moving.

Mr. J. Dutton Steele discussed the inevitable features of rapid transit, which he regarded as necessarily implying an elevated railway and a narrow gauge. Mr. Charles E. Emery thought that even if an endless railroad were not desirable, the system of landing passengers on a moving train by a subsidiary railroad was worth considering. If the friction system was unadvisable, the supplementary road at the side might have its cars drawn by light engines

till their speed equaled that of the rapid train, and then the two trains be coupled at the sides till the passengers to be added or left were transferred.

There was a discussion on the shape of rails, in which Mr. Holley, who knows more about Bessemer steel than any other member of the Convention, gave a lucid explanation of the laws which regulate the composition of rails, depending on the different kinds of strains to which the parts of the rail are subjected.

IRON AND STEEL NOTES.

TESTS OF THE STRENGTH OF IRON AND STEEL.—The importance of the Commission lately authorized by Congress to determine the strength of iron, steel, and other metals, will appear from the following considerations: So undetermined is the safe working load of different metals and of different structural forms that the professional rule is to subject bridges, roofs, and general machinery, to but one-sixth of the loads that are supposed to be great enough to break them. Although this rule is wasteful of material in most cases, it does not insure safety in all. In the fear that structures may be too weak, they are overloaded with costly materials; yet, despite this precaution, bridges, roofs, and floors give way, and machinery is perpetually breaking down.

The problem is by no means a simple one. Because an inch square bar will stand a certain load, it does not follow that each square inch section of every bar will sustain the same load. The resistance of a simple structure formed of bars—for instance the end-post of an iron bridge—is notably changed by no less than seven conditions, namely, the chemical constitution of the material, its temper and initial strains, due to manufacture, the length of the members of the structure, their thickness, their shape, the dimensions of the structure as a whole, and the arrangement of its parts with reference to the number and direction of strains. In other cases, the character of the stress — impact, vibration, or statical load—also changes the conditions of strength. Nor is the ultimate resistance of the material the criterion of safety; it is the resistance within the limit of elasticity. The former is comparatively easy—the latter difficult to determine. Then there is the apparatus for accurately weighing strains reaching to a thousand tons, and for measuring changes of figure under stress to less than the thousandth of an inch. The useful formulation of results, and the deduction of general laws from the numerous phenomena developed, is the crowning feature of the undertaking. These considerations give some idea of the magnitude and importance of the work before the Commission.

Judging from the character of the experts appointed by the President to do this work, we may reasonably expect results of great and far-reaching usefulness. Colonel Laidley, of the Ordnance, Colonel Gillmore, of the Engineers, Commander Beardslee, and Chief-Engineer David Smith, of the Navy, and Prof. Thurston, are not only competent mathematicians and professional observers of the uses and tests of materials, but they are trained experimenters in this very direction. For instance, Colonel Gillmore is the foremost authority, abroad as well as at home, on limes, cements, and artificial stone. General Sooy Smith is an experienced bridge builder and civil engineer, and Mr. A. L. Holley is a mechanical engineer and a practical metallurgist and steel maker.

The work the Commission has laid out is not narrow and incomplete. It involves not merely testing and branding specimens sent in by different makers, (which is very important as far as it goes,) but in several respects it embraces features never before undertaken by Government Boards, or on a comprehensive basis. Two of these features deserve special mention:

First—The combination of chemical and mechanical tests. It is now well settled that the effects of carbon and of the metalloids upon iron, and upon each other in combination with iron, produce as many physical characters as there are uses for iron and steel. Determining the behavior of materials under stress merely proves that substances adapted to various uses are in existence; what these substances are, and how they may be reproduced, is taught only by chemical analysis. Perhaps the highest usefulness of these combined tests will be the development of greater strength, toughness, hardness, and various other resistances to innumerable varieties of stress—the establishment of scientific synthesis in the manufacture of materials, by means of which they may be perfectly adapted to their uses, thus largely economizing cost and promoting safety.

Second.—The testing of structures and parts of structures of the sizes actually employed, and under the conditions of actual service. Few bridges fail because the ultimate resistance of a bar of the iron composing them is unknown to their builders. Many bridges break down because no builder has yet determined by anything short of the breaking down itself, the exact effect of compound strains on compound structures; and even this does not give the laws of resistance. When a bridge-post, for instance, carries but a sixth of the weight that a specimen of its material will bear, it may fail. The Commission purposes subjecting, in each of their standard forms, whole bridge-posts, and whole sections of bridge chords and whole floors of girders and whole large structures, just as they are used, to destructive stress; to measure the stress and its effects at each stage, and to deduce laws of resistance which will enable engineers to develop better forms, thus dispensing with an unnecessary margin of safety, and promoting actual safety and economy. In short, it proposes to grapple with these great practical problems just as they are presented, and not to skirmish around them by breaking little iron rods, and then figuring out conclusions in which a small error is magnified at every step.

Such experiments will occupy years of careful work and many thousands of dollars in

money ; but what an insignificant percentage this cost will be upon the millions now wasted in overloading on the one hand and in failure on the other. Whatever degree of improvement later years have witnessed in the constructive arts is due to such researches as these, limited and imperfect though they may have been. It is the duty of this commission, and we believe that it will be its privilege, to determine the laws by which the safety and economy of engineering structures are to be largely increased.—*N. Y. Times.*

Organization of the U. S. Board appointed to test Iron, Steel, etc.

President, Lt. Col. T. T. S. Laidley, U. S. A., Commander L. A. Beardslee, U. S. N., Lt.-Col. Q. A. Gillmore, U. S. A., Chief Eng'r David Smith, U. S. N., W. Sooy Smith, C. E., A.L. Holley, C. E., R. H. Thurston, C. E., Secretary.

Standing Committee of the Board.

(A) On Abrasion and Wear—R. H. Thurston, C. E., Chairman, A. L. Holley, C. E., Chief Eng'r D. Smith, U. S. N.

Instructions :—To examine and report upon the abrasion and wear of railway wheels, axles, rails and other materials, under the conditions of actual use.

(B) On Armor Plate.—Lt. Col. Q. A. Gillmore, U. S. A., Chairman, A. L. Holley, C. E., R. H. Thurston, C. E.

Instructions :—To make tests of Armor Plate, and to collect data derived from experiments already made to determine the characteristics of metal suitable for such use.

(C) On Chemical Research.—A. L. Holley, C. E., Chairman, R. H. Thurston, C. E.

Instructions :—To plan and conduct investigations of the mutual relations of the chemical and mechanical properties of metals.

(D) On Chains and Wire Ropes.—Commander L. A. Beardslee, U. S. N., Chairman, Lt. Col. Q. A. Gillmore, U. S. A., Chief Eng'r D. Smith, U. S. N.

Instructions :—To determine the character of iron best adapted for chain cables, the best form and proportions of link, and the qualities of metal used in the manufacture of iron and steel wire rope.

(E) On Corrosion of Metals.—W. Sooy Smith, C. E., Chairman, Lt. Col. Q. A. Gillmore, U. S. A., Cammander L. A. Beardslee, U. S. A.

Instructions :—To investigate the subject of the corrosion of metals under the conditions of actual use.

(F) On the Effects of Temperature.—R. H. Thurston, C. E., Chairman, Lt. Col. Q. A. Gillmore, U. S. A., Commander L. A. Beardslee, U. S. N.

Instructions :—To investigate the effects of variations of temperature upon the strength and other qualities of iron, steel and other metals.

(G) On Girders and Columns.—W. Sooy Smith, C. E., Chairman, Lt. Col. Q. A. Gillmore, U. S. A., Chief Eng'r D. Smith, U. S. N.

Instructions :—To arrange and conduct experiments to determine the laws of resistance of beams, girders and columns to change of form and to fracture.

(H) On Iron, Malleable.—Commander L. A. Beardslee, U. S. N., Chairman, W. Sooy Smith, C. E., A. L. Holley, C. E.

Instructions :—To examine and report upon the mechanical and physical proportions of wrought Iron.

(I) On Iron, Cast.—Lt. Col. Q. A. Gillmore, U. S. A., Chairman, R. H. Thurston, C. E., Chief Eng'r D. Smith, U. S. N.

Instructions :—To consider and report upon the mechanical and physical properties of cast iron.

(J) On Metallic Alloys.—R. H. Thurston, C. E., Chairman, Commander L. A. Beardslee, U. S. N., Chief Eng'r D. Smith, U. S. N.

Instructions :—To assume charge of a series of experiments on the characteristics of alloys, and an investigation of the laws of combination.

(K) On Orthogonal Simultaneous Strains.—W. Sooy Smith, C. E., Chairman, Commander L. A. Beardslee, U. S. N., R. H. Thurston, C. E.

Instructions :—To plan and conduct a series of experiments on simultaneous orthogonal strains, with a view to the determination of laws.

(L) On Physical Phenomena.—W. Sooy Smith, C. E., Chairman, A. L. Holley, C. E., R. H. Thurston, C. E.

Instructions :—To make a special investigation of the physical phenomena accompanying the distortion and rupture of materials.

(M) On Re-heating and Re-rolling.—Commander L. A. Beardslee, U. S. N., Chairman, Chief Eng'r D. Smith, U. S. N., W. Sooy Smith, C. E.

Instructions :—To observe and to experiment upon the effects of re-heating, re-rolling, or otherwise re-working ; of hammering, as compared with rolling and of annealing the metals.

(N) On Steels produced by Modern Processes.—A. L. Holley, C. E., Chairman, Chief Eng'r D. Smith, U. S. N., W. Sooy Smith, C. E.

Instructions :—To investigate the constitution and characteristics of steels made by the Bessemer, open hearth, and other modern methods.

(O) On Steels for Tools.—Chief Eng'r D. Smith, U. S. N., Chairman, Commander L. A. Beardslee, U. S. N., W. Sooy Smith, C. E.

Instructions :—To determine the constitution and characteristics, and the special adaptations of steels used for tools.

RAILWAY NOTES.

Steel Rails for California.—It is gratifying to know that the Pacific Coast, which has never felt the effects of our great panic, is coming to the rescue of the Eastern iron trade. Recently the Southern Pacific Railroad Company of California contracted with the Pennsylvania Steel Company and the Bethlehem Iron Company for 10,000 tons of steel rails—5,000 from each company—to be used in continuing the line of the road south of Los Angeles in the direction of Fort Yuma, the southern terminus of the road, at the junction

of the Colorado and Gila Rivers. The distance by rail from San Francisco to Fort Yuma is 722 miles. At Fort Yuma the Southern Pacific will connect with the Texas Pacific (Col. Scott's road), and farther north, at Fort Mohave, on the Colorado River, another eastern connection is expected to be made in time. The steel rails ordered are to weigh 50 pound to the yard, and the quantity ordered will lay 100 miles of single track, including sidings.

The rails will be shipped to Jersey City by rail, and thence by sailing vessels around Cape Horn to San Francisco. The freight from San Francisco will not exceed $10 a ton, and is expected to be a dollar or two less. The rails will serve admirably as ballast for light cargoes.

We hope that this transaction may be but the beginning of a large trade in steel rails and iron and steel products generally between the east and the Pacific coast. The states and territories of the Pacific slope consume annually about 300,000 tons of iron in all forms, and until they are ready to make their own iron and steel it would certainly be wise for them to buy their supplies from sister states rather than from foreigners. They will thus save money and be better served. Heretofore California has been a large importer of iron and steel products. In the fiscal year ended June 30, 1874, her imports of these articles aggregated $1,555,000.—*Bulletin Iron and Steel Association.*

BRAKE TRIALS.—The Royal Commission on Railway Accidents, which has lately been taking evidence in different towns in the country upon means for diminishing the frequency of disasters on the iron highways of the country, have asked the Railway Companies' Association to make experiments with continuous brakes. The Railway Companies' Association has consented, and a piece of level line on the Nottingham and Lincoln branch of the Midland Railway has been selected. Several continuous brakes will be brought forward for trial—amongst them the Westinghouse, the Barker brake, Clark's chain brake as improved by Webb, vacuum brakes, and others. Mr. Edward Woods, C. E., of Westminster, has been appointed to conduct the trials, and Colonel Inglis, R. E., is associated with him. The experiments commence on the 9th proximo, and we believe every care will be taken to render the tests exhaustive, both for the information of the Royal Commission and for the guidance of railway managers and engineers. To carry out such a series of tests as will settle the question as to which is the best continuous brake, can be no easy matter, but due precautions will, we hope, be taken to secure a good result.

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ENGINEERING PROJECTS IN EGYPT. — An Egyptian correspondent, writing recently, says: "The Soudan Railway is being rapidly pushed forward. Various schemes are also under consideration for the better irrigation of Lower Egypt. One proposal is for the construction of a series of locks and weirs on the existing canals, which during high Nile are so many deep and rapid rivers. Another is for the construction of canals taken from a high level on the river, in upper Egypt, and distributing the water thus obtained over the surface of the Delta. But it must be remembered that, great as is the volume of water in the stream, it is precisely when the river is at its lowest that the cotton crop requires most irrigation. Perhaps, after all, the moderns could not do better than follow the example of the old Egyptians and construct another Lake Mœris as a vast reservoir for the surplus waters; at all events, his Highness has at his command engineering skill second to none in the world."

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A COURSE IN DESCRIPTION GEOMETRY FOR THE USE COLLEGES AND SCIENTIFIC SCHOOLS, by WM. WATSON, Ph. D. 4to. portefolio cloth. London: Longman, Green & Co. 1875. For sale by D. Van Nostrand. Price $7.00

The contents of this work comprise Problems of Position relating to the Point, the Right Line, and Plane, the General Method of Rotations; the Method of Changing the Coordinate Planes; Plane Curves and their Tangents; Curves of Error; Cylinders; Cones; and Surfaces of Revolution; Tangent Planes; Section Planes; Intersection of Surfaces; Spherical Projections; Developable Surfaces; Warped or Skew Surfaces. The text is accompanied by 32 elegant quarto plates engraved by distinguished European artists. The appendix contains 36 stereoscopic views, engraved on steel, by Rigel, of Nuremberg. The latter, many of which are elaborately colored, are designed to supersede for the student the use of the costly models generally employed to illustrate this subject. It is believed and hoped by the author that the work will be found the most completely illustrated practical treatise on descriptive geometry in the English language.

STORMS: THEIR NATURE, CLASSIFICATION AND LAWS. By WM. BLASIUS. Philadelphia: Porter & Coates. For sale by D. Van Nostrand. Price $2.50.

This work will prove an interesting addition to the literature of Meteorolgy, whether it affords sound instruction or not. The author's explanation of his method in beginning his researches cannot be read without feeling respect for the opinions founded on such systematic methods. We remember perfectly the storm in Middlesex County, Massachusetts, whose track the author studied and mapped, and we remember to have adopted opinions at the time, which the author gives sufficient reasons for abandoning. The chart of this storm, which he calls the West Cambridge Tornado, forms a fitting frontispiece to the work, while the description of the debris along its track, and the author's analysis of it, forms the introductory chapter,

The theories of Redfield, Espy & Dove are all discussed and rejected. The views offered as substitutes are urged in a fair spirit and with an abundant knowledge of the physical facts.

The book appears at a good time, the widespread and growing interest in the subject will doubtless insure a wide circle of readers. It possesses one merit wanting in the standard works on Meteorology, and that is convenient size. There is nothing in its dimensions to discourage the general reader from attempting to read this author through; at the same time the maps and other illustrations, without being marvels of art, suggest a clear elucidation of the subject.

PLATTNER'S MANUAL OF QUALITATIVE AND QUANTITATIVE ANALYSIS WITH THE BLOWPIPE. From the last German Edition. Revised and enlarged by Prof. TH. RICHTER. Edited by T. HUGO COOKESLEY. London: Chatto & Winders.

We fear there is a growing disregard of the eighth commandment; at least there is a strong bit of testimony to this effect in this very respectable looking English book. The title page justifies the expectation of a new translation of the celebrated German work, but examination proves it to be an accurate copy, so far as it goes, of the excellent translation by Prof. Cornwall. (New York: D. Van Nostrand, 1872),

The preface is as misleading as the title page. We give it entire.

"A work like the present needs but a short preface. A good book on the Blowpipe has long been wanted in England, and it is because of the increasing importance of Analysis by means of this instrument that I have edited the great work of Plattner.

While staying, last year, at the Freiburg Mining Academy, Saxony, I was so impressed with the perfection to which the use of the Blowpipe has been brought by the German teachers who use Plattner's work as a textbook, that I resolved to give English students the benefit of Plattner's researches.

The first English translation of this work was issued in New York, and I have followed generally the translation of the American edition, omitting, however, some few portions

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This the last Annual Catalogue or Register of Columbia College has just been published. It forms a thick octavo volume of 265 pages. It contains a list of all the officers and students in the different Schools of "Letters and Science," "Mines," "Law," and of "Medicine," with general information as to each, a detailed description of each Department of Instruction, with plan of the new Building for the School of Mines, the Course of Study, Rules of Order, Prizes, Scholarships, Officers of the different Alumni Associations, Honor Men, Graduates, Degrees, Scheme of Attendance, Lecture Courses, Text Books, Examination Papers, etc., etc.

A COURSE IN DESCRIPTION GEOMETRY FOR THE USE COLLEGES AND SCIENTIFIC SCHOOLS, by WM. WATSON, Ph. D. 4to. portefolio cloth. London: Longman, Green & Co. 1875. For sale by D. Van Nostrand. Price $7.00

The contents of this work comprise Problems of Position relating to the Point, the Right Line, and Plane, the General Method of Rotations; the Method of Changing the Coordinate Planes; Plane Curves and their Tangents; Curves of Error; Cylinders; Cones; and Surfaces of Revolution; Tangent Planes; Section Planes; Intersection of Surfaces; Spherical Projections; Developable Surfaces; Warped or Skew Surfaces. The text is accompanied by 32 elegant quarto plates engraved by distinguished European artists. The appendix contains 36 stereoscopic views, engraved on steel, by Rigel, of Nuremberg. The latter, many of which are elaborately colored, are designed to supersede for the student the use of the costly models generally employed to illustrate this subject. It is believed and hoped by the author that the work will be found the most completely illustrated practical treatise on descriptive geometry in the English language.

STORMS: THEIR NATURE, CLASSIFICATION AND LAWS. By WM. BLASIUS. Philadelphia: Porter & Coates. For sale by D. Van Nostrand. Price $2.50.

This work will prove an interesting addition to the literature of Meteorolgy, whether it affords sound instruction or not. The author's explanation of his method in beginning his researches cannot be read without feeling respect for the opinions founded on such systematic methods. We remember perfectly the storm in Middlesex County, Massachusetts, whose track the author studied and mapped, and we remember to have adopted opinions at the time, which the author gives sufficient reasons for abandoning. The chart of this storm, which he calls the West Cambridge Tornado, forms a fitting frontispiece to the work, while the description of the debris along its track, and the author's analysis of it, forms the introductory chapter,

The theories of Redfield, Espy & Dove are all discussed and rejected. The views offered as substitutes are urged in a fair spirit and with an abundant knowledge of the physical facts.

The book appears at a good time, the widespread and growing interest in the subject will doubtless insure a wide circle of readers. It possesses one merit wanting in the standard works on Meteorology, and that is convenient size. There is nothing in its dimensions to discourage the general reader from attempting to read this author through; at the same time the maps and other illustrations, without being marvels of art, suggest a clear elucidation of the subject.

PLATTNER'S MANUAL OF QUALITATIVE AND QUANTITATIVE ANALYSIS WITH THE BLOWPIPE. From the last German Edition. Revised and enlarged by Prof. TH. RICHTER. Edited by T. HUGO COOKESLEY. London: Chatto & Winders.

We fear there is a growing disregard of the eighth commandment; at least there is a strong bit of testimony to this effect in this very respectable looking English book. The title page justifies the expectation of a new translation of the celebrated German work, but examination proves it to be an accurate copy, so far as it goes, of the excellent translation by Prof. Cornwall. (New York: D. Van Nostrand, 1872),

The preface is as misleading as the title page. We give it entire.

"A work like the present needs but a short preface. A good book on the Blowpipe has long been wanted in England, and it is because of the increasing importance of Analysis by means of this instrument that I have edited the great work of Plattner.

While staying, last year, at the Freiburg Mining Academy, Saxony, I was so impressed with the perfection to which the use of the Blowpipe has been brought by the German teachers who use Plattner's work as a textbook, that I resolved to give English students the benefit of Plattner's researches.

The first English translation of this work was issued in New York, and I have followed generally the translation of the American edition, omitting, however, some few portions

which I have thought superfluous. I have also omitted the long list of minerals given under each heading, as iron, lead, &c., amounting to several hundreds in the German edition. However useful such lists may be as a mineralogical reference, still they hardly belong to the province of the Blowpipe. The headings of the different combinations, and all the principal minerals, however have been retained, and their characteristics fully described as in the German original. I have added a new drawing and description of a mechanical blowpipe, which is the only one which is at once portable and thoroughly simple and effective. It would not have been a very laborious or difficult task for me to have greatly reduced the size of the book, but I have thought it better, as Plattner may be justly called the father of this department of analysis, to edit the work in its entirety.

In commending the volume to the English student, I need only add that it is by far the most complete work extant on a subject both of growing practical importance and of extreme interest."

Now this preface, brief as it is, is very nearly the sum total of Mr. T. Hugo Cookesley's work in connection with this volume, all the rest is Prof. Cornwall's translation; abbreviated somewhat but otherwise unaltered. There is not the slightest acknowledgment of this latter gentleman's work that we can find in the book, nor is there any mention of his name save in the last two paragraphs of the appendix where "Mr. Cornwall" is mentioned as a person holding some opinions on the subject of qualitative tests for potassa and bismuth.

Even the few definite statements of the preface are affected with a rather large personal equation. "A new drawing and description of a mechanical blowpipe" is referred to as though it were an important alteration of the original work. The fact is, it is only a badly modified diagram of the same instrument described on page 7 of the American edition.

The claim that the book "is by far the most complete work extant" on this subject, is of course simply absurd, in view of the fact that the valuable lists of minerals of both American and German editions are omitted. We can see substantial reasons for suspecting that there is no real person claiming the name of editor, but that it simply is a device of the publishers to evade the responsibility of doing what is characterized in the preface as *following generally* the American translation. The work is just such as could be done at the printer's from a copy of Prof. Cornwall's translation, with the general instruction to omit the lists of mineralogical names and symbols where the liability to error in following copy was greater than usual. No skilled labor in editing higher than this, is anywhere apparent in the volume.

If there is a T. Hugo Cookesley, the reputation he has recently earned is not enviable.

A Grammar of Coloring. By G. Field. New edition, revised. London: Lockwood & Co. For sale by D. Van Nostrand. Price $1.00.

This is one of the re-issues which are being made of a good many of the original treatises comprised in "Weale's Series;" the "Grammar of Coloring" being that of Field, re-edited, with additions, by Mr. Ellis A. Davidson. Field's treatise must not be confounded with his wellknown one on color in the wider sense; the present treatise being an entirely practical one, on the varieties and qualities of the pigments used in coloring, and the media and (to some extent) the processes of manipulation employed. A good deal of what is included under this latter head is supplied by the editor, who gives directions for the preparation of paper, canvas, and other materials for paintng on, the choice and use of brushes, &c.; and also a chapter on the characteristic features of the various styles of ornament; the latter, however, is only of an empirical nature, and not intended, probably, to do more than give a general notion of the matter to decorative painters. Otherwise the book is a most useful *resume* of the properties of pigments, one for reference rather than reading. In re-editing, however, it should have been pointed out that the old division of primary and secondary colors (which, as far as pigments are concerned, is the practically correct one) can hardly be alluded to now without at least a reference to the newer theory on the subject evolved by Professor Church and others, from the study of the combinations of colored rays, instead of pigments, and in which green usurps the former place of yellow as a primary. The point is of more theoretical than practical importance, certainly; but the results arrived at in Professor Church's experiments are too striking to be passed over in any book in which the subject is touched upon.—*Builder.*

Elements of Euclid Adapted to Modern Methods in Geometry. By James Bryce, M. A., LL. D., and David Munn, F. R. S. E. London and Glasgow: W. Collins, Sons & Co. 1874.

The editors of this improved edition of the time-honored Elements of Geometry, which has held its own as a text-book for ages and which is not likely to be superseded, approach their task with profound respect for the venerable author whose work they aim at amending in some degree. Any attempt to supplant it altogether they strenuously deprecate. Not only, they say, has Euclid's great work received the approval of many successive ages, and served to connect the science of the present with that of the past, but even now, in the advanced state both of the Pure and the Applied Mathematics, it is open to criticism on very few points; and with true conservatism they urge the paramount importance of its retention, not only as a common standard of reference, but also as one by which the "purity and rigorous character of geometrical demonstrations shall be maintained, and a true logical sequence kept up in the order in which these are presented to the mind of the student." The improvements introduced are of three classes. An attempt has been made to incorporate in the work certain geometrical methods which have an important relation to those of the

modern analysis, where that could be done without abandoning the strict methods of Euclid; the order of the propositions has been altered in several cases, so as to make the connection between them more apparent; and the proofs have been shortened where that could be done without omitting any link in the chain. Each of the six books used in this manual is followed by an appendix, in which are placed supplementary propositions and a series of theorems and problems for the exercise of the student, gradually increasing in difficulty, and related as far as possible to the order of the propositions.

PRINCIPLES OF MECHANICS AND THEIR APPLICATION TO PRIME MOVERS, &c. By W. J. MILLAR, C. E. London: E. & N. Spon. 1874. For sale by D. Van Nostrand. Price $2.

Mr. Millar, who ably officiated as the successor of Professor Rankine in the period between the death of that eminent teacher and the filling up of the professorial vacancy, has here published a carefully revised abstract of the lectures then delivered by him to Professor Rankine's Class of Civil Engineering and Mechanics. The area occupied by these lectures was an extensive one, including over fifty important branches and a considerably larger number of subsidiary ones, such as water and steam power motors, naval and architectural construction, thermo-dynamics, water supply, &c. To compress this into a small manual requires very considerable power of concentration, and the exercise of great judgment in the elimination of all matters not strictly essential to the subject in hand. In both respects Mr. Millar's book deserves praise; and, on account of the qualities of this kind which it displays, the conciseness and quantity of the information it supplies, and its general correctness, it must take a high place as an important addition to the educational literature of the mechanical arts.

PRINCIPLES OF METAL MINING. By J. H. COLLINS, F. G. S. Collins' Elementary Science Series. London and Glasgow: W. Collins, Sons & Co. 1875. For sale by D. Van Nostrand. Price 75 cents.

This is an excellent compendium of the methods employed in an important industry, and it is the more reliable from being the work of a practical miner. In his introduction, Mr. Collins, although advising the tyro to gather information from books and every other available source, wisely insists that the art of mining must, to a great extent, be learnt at the mine. Still, the practical miner will learn much from such a work as the present, and a manual so complete and popular will be especially serviceable at the present time, when a strong desire is shown by the best of the mining population to attain a scientific knowledge of their profession. Mr. Collins commences with a plain treatise on the geology of the subject, and follows with an exposition of the practical department of his art, describing not only the methods, but also the tools employed, and noting the comparative value of each. Apparatus for draining and ventilation also occupy one or two chapters, and examination questions, a full glossary of terms, and a copious index are appended.—*Iron.*

AN ELEMENTARY EXPOSITION OF THE DOCTRINE OF ENERGY. By D. D. HEATH, M. A. Longmans, Green & Co. For sale by D. Van Nostrand. Price $2.25.

In this book we have a very good elementary exposition of the Doctrine of Energy; perhaps, however, better adapted for the use of schools than for the general public. Indeed, we are told in the preface that the work was developed from a set of lectures given to the senior classes of Surrey County School.

After dismissing the subject of fundamental units, the writer goes on to dynamical energy, a subject which is fully and fairly discussed. The author next proceeds to thermal and other energies, and ends by a brief account of molecular theories. If we have any fault to find, it is that undue preference seems to be given to the British system of units, while the decimal system is overlooked.

The author, as he tells us in his preface, has endeavored to give the young student some conception of the *possibility* of explaining the conservation of energy by the theory that all phenomenal changes are really in themselves changes of motion and position among the molecules or ultimate atoms of substances; and he adds the hope that he has succeeded in presenting this as exhibiting a probable surmise, which may be false without vitiating the doctrine previously developed.

This strikes us as being very well put. The conservation of energy would hold if we imagine the universe to be composed of ultimate atoms, with forces acting in lines between them; but should it be found that this last conception is inapplicable to portions of the universe, as, for instance, the medium which conveys light, nevertheless it does not follow that the conservation of energy does not still hold true.—*Nature.*

THE COMMERCIAL HANDBOOK OF CHEMICAL ANALYSIS. By A. NORMANDY. New edition, enlarged by HENRY M. NOAD, Ph. D., F. R. S. London: Lockwood & Co. 1875. For sale by D. Van Nostrand. Price $6.25.

When the late Dr. Normandy first published his work on Commercial Analysis the Adulteration Act did not exist, and the book was chiefly used by chemical manufacturers and by the small class of practical analysts. Dr. Noad's enlarged edition of the work appears very opportunely, and it will be found to be essential to the analysts appointed under the new Act. It contains, in alphabetical order, a concise list of all ordinary substances which can require to be analysed in connection with food and drink, and in addition the methods of analysing many substances which can only be required in special manufactures, or are only used as drugs. Each article commences with an account of the substance in its pure state; this is followed by a list of the most common impurities or adulterations, and then by the best means of detecting them. The adulterations of some common commodities are somewhat startling; thus, bread may contain rye and barley flour, oatmeal, pea and bean meal,

potato starch and rice flour, while of mineral constituents there may be lime, alum, magnesia, ground soapstone and sulphate of copper. The substances sometimes employed to color sweetmeats, liqueurs, jellies, &c., include some of the most fatal poisons, such as the acetate, arsenite and carbonate of copper, chromate and iodide of lead, and the sulphides of arsenic and mercury. Indeed, we well remember going over a sweetmeat manufactory, and on remarking on the bright yellow color of some large comfits we were told that chrome yellow was employed to produce it, our informant evidently having no idea that the substance is a most virulent poison. A long article is devoted to the adulteration and fabrication of wines, and the "plastering" and "fortifying" of sherries is discussed at length. In all cases the most recent results are given, and the work is well edited and carefully written. A glossary at the end of the book will be found useful both to the analyst and the student.—*Nature.*

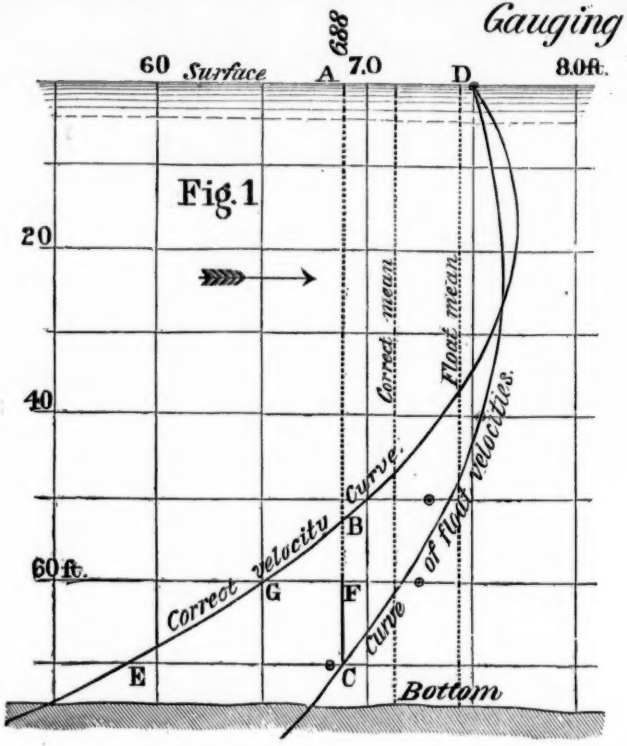
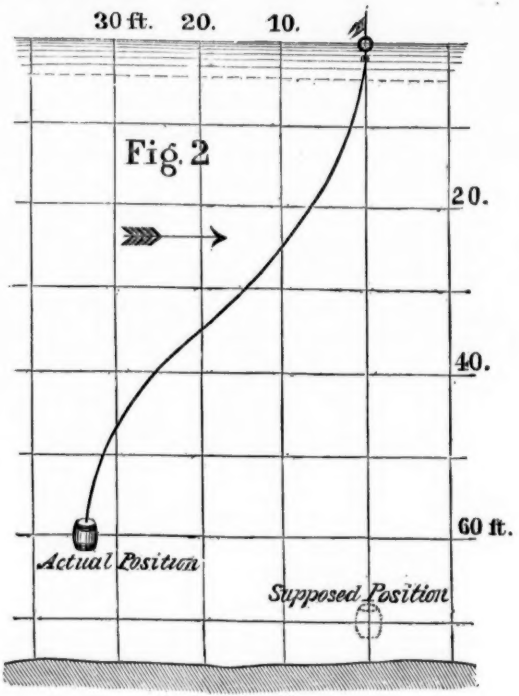
MISCELLANEOUS.

THE exact period when the art of manufacturing glass was first introduced into England is not easily determined. It is said to have been brought into the country in 1557; and the finer sort of window glass was then made at Crutched Friars, in London. The first flint glass made in England was manufactured at Savoy House in the Strand, and the first plate glass for looking glasses, coach windows, etc., was made at Lambeth in 1673, by Venetian workmen brought over by the Duke of Buckingham. The date of the introduction of the art of glassmaking into Scotland is more easily determined, because of more recent occurrence. It took place in the reign of James VI. An exclusive right to manufacture glass within the kingdom for the space of thirty-one years was granted by the monarch to Lord George Hay in the year 1610. The right his lordship transferred in 1627, for a considerable sum, to Thomas Robinson, merchant tailor, London, who again disponded of it for £250 to Sir Robert Mansell, Vice-Admiral of England. The first manufactory of glass in Scotland, an extremely rude one, was established at Wemyss, in Fife. Regular works were afterwards established at Prestonpans and at Leith. A bottle was blown at the Leith glass works, January 7th, 1747, of the extraordinary capacity of 105 imperial gallons.

M. VIOLLE considers that the emissive power of the sun at a given point on its surface will be the relation between the intensity of the radiation emitted at such point and the intensity of radiation which a body, having an emissive power equal to unity and carried to the temperature of the sun at the considered point, would possess. So that he defines the true temperature of the sun as the temperature which a body of the same apparent diameter as the sun should possess in order that this body having an emissive power equal to the average of the solar surface may emit, in the same period, the same quantity of heat as the sun. From experiments made at different altitudes, M. Violle determines the intensity of the solar radiation, as weakened by passage through the atmosphere, and finds, for the effective temperature of the sun, 2,822 deg. Fah. Investigations conducted with an actinometer by the dynamic method lead the investigator to conclude that steel, as it emerges from a Siemens-Martin furnace, has a temperature of 2,732 deg. Fah. If it be admitted that the average emissive power of the sun is sensibly equal to that of steel in a state of fusion, determined under like conditions, it appears that the mean true temperature of the solar surface is about 3,632 deg. Fah.

IT appears from the following that iron water pipes have a distinct chemical value. Professor Medlock proved by analysis, several years ago, that iron by its action on nitrogenous organic matter produces nitrous acid, which Muspratt called "Nature's scavenger." The latter chemist found, as a general result, that, by allowing water to be in contact with a large surface of iron, in about forty-eight hours every trace of organic matter was either destroyed or rendered insoluble, in which state it could be purified effectually by filtration. Medlock found, on examining the water at Amsterdam, which smelt and tasted badly, that the sediment charred on ignition, and was almost consumed, showing that it consisted of organic matter. He also found that water, instead of taking iron from the service pipes, before entering them contained nearly half a grain of iron to the gallon; while in the water issuing from the pipes, there was only an unweighable trace.

Before entering the reservoir, the water holding iron in solution formed no deposits, while the water coming from the pipes, and freed from iron, gave organic sediment above mentioned. He then made analysis of water brought in contact with iron, and water not in contact, with the result that the water which had not touched iron contained 2.10 grains of organic matter, and 0.96 grain iron; the other gave only a slight trace of both, showing plainly that the organic matter in the water was either decomposed or thrown down by contact with iron, and this water, when filtered, was found to be clear, of good taste, with no smell, and free from organic matter. It is not stated in what shape the iron was held in solution, but it was probably in that of carbonate, the usual iron salt of springs.

SOME weeks since a notice appeared in our pages of the use of a plain disc for cutting steel rails cold. Mr. T. L. Lewis, of Pittsburgh, states that for some years past M. Carnegie, Kloman & Co., of Pittsburgh, have been using a plain disc to cut large iron beams cold, and since its introduction there that many other American mills have been using it for the same or similar purposes.—*The Engineer.*

Gauging of Rivers.